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Performance of mango (*Mangifera indica*) based agri-horticultural systems under rainfed plateau conditions of eastern India

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ABSTRACT

An attempt was made at ICAR RCER, Research Centre, Ranchi to analyse the plant growth behavior, productivity of different component crops, profitability, soil fertility status and carbon sequestration potential of 20 different agri horticultural systems during young bearing stage (6th to 10th year) of mango plants. The field trial was established during the year 1999-2000 to standardize suitable filler crop and intercrop combinations for mango based agri-horticultural systems under rainfed uplands of eastern plateau and hill region. The study indicated enhanced growth of mango and filler plants with paddy as intercrop. With respect to soil fertility, reduction in the content of available nitrogen and potassium was recorded after 10 years of planting particularly under Mango + Guava + Paddy agri-horticultural system. Among all the systems, the maximum cumulative Rice equivalent yield was recorded under Mango + Guava + French Bean. During all the five years, the significantly higher REY was recorded in case of Agri-horti systems with either guava as filler crop or French bean as intercrop.

Key words: Agri-horticultural systems, Gamhar, Guava, Lemon, Mango

The agrarian scenario of eastern plateau and hill region of India is characterized by rainfed agriculture constrained with soil acidity, high rate of soil erosion, poor water holding capacity of soil (Nath *et al.* 2006). The low lands and the medium uplands are used for the rainfed rice production, whereas the uplands are seldom utilized for production of agronomical crops. These uplands are either used as open pasture or for social forestry as per the conditions. Further, due to the lower productivity of rainfed crops, growing agricultural crops is unprofitable under upland conditions. Fruit tree based production system can offer suitable option for profitable utilization of the uplands.

The region is suitable for successful cultivation of a number of fruit crops. Fruit crops like mango and guava constitute a major share of area expansion programme under fruit crops in the region. Long juvenile period, heavy mortality of the plants during the summer season due to grazing and lack of irrigation are two major factors which discourage the farmers to take up mango orcharding. Again, low productivity of mango under the uplands of this region makes mango cultivation, unprofitable under the eastern plateau and hill region. Hence, development of a profitable mango based production system with income from the first year onwards can help in alluring the farmers to take up mango orcharding. Integration of a precocious bearing filler plants in a multitier system can address to the need for income from the initial years of orchard establishment in mango. Economic advantages of mango based agri horticultural systems have been reported by number of workers (Pawar and Sarwade 2006, Ramaswamy 1997, Singh *et al.* 1996, Ratha and Swain 2006). However, meager information was available on performance of multitier agri-horticultural system under eastern plateau and hill region.

At ICAR RCER, Research Centre, Ranchi, a field trial was established during the year 1999-2000 to standardize suitable filler crop and intercrop combinations for mango based agri-horticultural systems under rainfed uplands of eastern plateau and hill region. During the initial five years of orchard establishment, guava has been found to be the most appropriate filler plant for improving the overall productivity (Nath *et al.* 2007). Changing light profile within the orchard due to the growing plant canopy influence the choice of intercrop to be grown at different ages of the orchard. Again, monitoring of soil fertility status in grown up mango based agri-horti systems can help in designing nutrient management strategies particularly under the low fertile soils of eastern plateau and hills so that the productivity of mango does not decline in long run. In the present paper, attempt has been made to analyse the plant growth behavior, productivity of different component

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crops, profitability and soil fertility status of different agri horticultural systems during young bearing stage (6^{th} to 10^{th} year) of mango plants.

MATERIALS AND METHODS

The investigations were undertaken at ICAR Research Complex for Eastern Region, Research Centre, Ranchi, Jharkhand, India located at the latitude of 28^0 38' 22" N and 38^0 39' 05" N and longitude of 77^0 9' 45" E and 77^0 10' 24"E at an average elevation of 228.61 m above the mean sea level. The experiment was laid out during 2000-01 in a Factorial Randomized Design with three replications. The treatments comprised mango cv Langra as main crop (spacing 10m × 10m, accommodating 100 plants per ha), four filler plants (Guava, i.e. *Psidium guajava* cv Allahabad Safeda, lemon, i.e. *Citrus limon* cultivar Nepali oblong, gamhar, i.e. *Gmelina arborea* and no filler) planted at a spacing of 5 m × 5 m within the rows and between the mango plants (300 plants per ha), five intercrops, viz. cowpea (grain legume), French bean (grain legume), paddy (staple food), *Stylosanthes hamata* (fodder) and fallow. Hence, the experiment consisted of a total of 20 numbers of treatment combinations. The intercrops were grown as *kharif* crop (rainy season crop) under rainfed conditions. Observations on plant height, canopy spread, canopy volume of main crop and filler crops were recorded during 2006 to 2010 and data on plant growth parameters during 2010 has been presented in the paper. For the value of canopy spread, the mean of spread (east-west) and spread (north-south) was considered. The tree volume of mango was estimated using the formula:

Tree volume (m^3) = (4/3)* π*(canopy spread (east-west)*canopy spread (north-south)*plant height/8)

Tree volume of gamhar was estimated using the formula given by Akinnifesi (1995) which is as follows: $V = 0.0345 + 0.000\ 8\ D^2$ (R^2=0.936)

Data on light profile in different agri-horticultural systems were recorded with the help of Lux meter during 2006-10 at a distance of 2.0 m, 3.0 m and 5.0 m from the trunk of mango plants and 1.0 m, 2.0 m and 5.0 m from the trunk of the filler plants and presented as % light incidence.

For estimation of rice equivalent yield of different components of agri-horti systems, the prevailing market price of the commodity during 2010 was considered (mango: ₹ 15/kg, guava: ₹ 12/kg, lemon: ₹ 12/kg, cowpea seeds: ₹ 40/ kg, French bean seeds: ₹ 40/kg, *Stylosanthes*: ₹ 1/ kg, Rice: ₹ 10/ kg).

Status of soil chemical properties was recorded during the 10^{th} year of planting. For this soil samples were collected at 0-30 cm and 30-60 cm soil depth at a distance of 2.0 m from the mango plants in each treatment. Content of organic carbon was measured used Walkley and Black's Rapid Titration method (Jackson 1973). Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija 1956). Available phosphorus was determined by Bray's method and estimated by spectrophotometer using ascorbic acid method (Tandon 1999). Available potassium was determined by flame photometer in soil solution prepared in extraction solution of normal ammonium acetate (pH 7.0) in ratio of 1:5 (w/v) (Tandon 1999).

The data were subjected to standard analysis of variance technique for factorial randomized block design (Gomez and Gomez 1984). Statistical analysis was done for the individual year data as well as pooled data over the years for different parameters. The mean effect of treatments were compared at $P<0.05$ level of significance.

RESULTS AND DISCUSSION

Plant growth of mango

Significant effects of the intercrops and interaction between filler plants and intercrops could be recorded on tree volume of 10 year old mango plants, whereas effect of filler plant was non-significant. As evident in the figure, the maximum tree volume was recorded in case of Mango + Guava + Paddy (58.52±12.34 m^3) which was at par with all filler crops with paddy as intercrop. Among the intercrops, paddy resulted in the maximum tree volume. Hence, the study indicated enhanced growth of mango plants with paddy as intercrop. Raut and Jain (2013) also recorded significant increase in the plant and spread of mango with intercropping of paddy under Central India conditions.

Plant growth of filler plants

The filler crops, differed significantly among each other with respect to different plant growth parameters (Table 1) and all the growth parameters followed the order Gamhar > Guava > Lime. In case of guava, intercropping

Table 1 Plant growth parameters of filler plants under different agri-horti systems

	Plant height (m)				Canopy spread (m)			
	Guava	Lemon	Gamhar	Average of intercrops	Guava	Lemon	Gamhar	Average of intercrops
Cowpea	2.16 ±0.28^c	2.18 ±0.31^c	12.39 ±2.64^b	5.57 ±1.64^y	2.32 ±0.31^d	1.39 ±0.26^e	2.64 ±0.20^c	2.11 ±0.25^z
French bean	2.84 ±0.39^c	1.64 ±0.26^c	10.94 ±2.39^b	5.14 ±1.32^z	3.18 ±0.42^b	1.34 ±0.24^e	3.16 ±0.28^b	2.56 ±0.31^x
Paddy	2.36 ±0.22^c	1.59 ±0.29^c	15.64 ±3.19^a	6.53 ±1.62^x	2.76 ±0.41^c	1.68 ±0.31^e	3.91 ±0.21^a	2.78 ±0.26^x
Stylosanthes	2.42 ±0.34^c	2.16 ±0.22^c	12.54 ±3.44^b	5.70 ±1.68^y	2.84 ±0.44^c	1.11 ±0.26^f	3.28 ±0.44^b	2.41 ±0.34^y
Fallow	2.14 ±0.36^c	1.19 ±0.31^c	12.49 ±3.61^b	5.27 ±1.66^z	2.29 ±0.53^d	1.55 ±0.28^e	2.64 ±0.29^c	2.16 ±0.29^z
Average of filler plants	2.38 ±0.32^q	1.75 ±0.26^r	12.86 ±3.28^p		2.67 ±0.41^q	1.41 ±0.26^r	3.12 ±0.27^p	

of French bean resulted in maximum canopy spread. Swain *et al.* (2012) have also recorded significant increase in plant growth of guava with intercropping of leguminous crops like cowpea and French bean. In case of lime, the minimum canopy spread was recorded with intercropping of stylosanthes. In case of gamhar, intercropping of paddy resulted in maximum tree height and canopy spread. Under alkali soils of north western India, Singh *et al.* (1997) have also recorded increased plant growth of timber plants like eucalyptus and poplar with intercropping of rice based crop rotations.

Light interception pattern

Data on light interception pattern below the canopy at different age of the trees is given in Table 2. As the data indicates, the light intensity below the mango trees decreased with the increasing tree age. The decrease was more pronounced at a distance of 3 m distance from the trunk although there was no effect of the filler plants on light intensity at this position of the mango trees. At 5 m distance from the trunk, decrease in the light intensity under mango trees was recorded during 2009 and 2010 with gamhar as filler plant. In case of all the filler plants, marked reduction in the light intensity was recorded over the years. The light intensity below the guava plants was higher than the other plants at a distance of 1 m during all the 5 years of observation. At a distance of 2 m from the trunk, although the light intensity below the filler plants decreased over the years, the pattern of decrease was inconsistent. During all the years, the light intensity at a distance of 2 m under the filler plants followed the order Gamhar>Guava>Lemon. According to Siebert (2002), shade trees protect the soil from adverse insolation, help maintain soil organic matter, reduce evaporation from soil, and retain soil productivity. Higher soil moisture benefits soil biota and decomposition. Hence, the inconsistencies on yield of intercrops recorded in the present investigations (discussed later) can be explained by the factors other than the effect of light intensity on photosynthetic efficiency of the crops.

Soil properties

The data on soil properties under different agri-horti systems have been presented in Table 3. The content of soil organic carbon varied significantly under different production systems. Although, in the 0-30 cm soil depth, significant effect of intercropping or filler crops was not recorded, the interaction effect between intercropping × filler plants was significant. The maximum organic carbon was recorded in case of Mango + Gamhar + French bean (0.66±0.08%) which was at par with Mango + Guava + Paddy. In the 30-60 cm soil layer, filler plants significantly affected the organic carbon content and the maximum content was recorded in case of gamhar (0.42±0.07%). Intercropping did not result in significant change in organic carbon in 30-60 cm soil layer. However, the interaction between filler plants and intercropping was significant and the maximum content was recorded in case of Mango +

Table 2 Changes in light interception below tree canopy (% of light intensity in the open area) under different tree combinations

	2006					2007					2008					2009					2010				
	Mango			Filler plant		Mango			Filler plant		Mango			Filler plant		Mango			Filler plant		Mango			Filler plant	
	2 m from trunk	3 m from trunk	5 m from trunk	1 m from trunk	2 m from trunk	2 m from trunk	3 m from trunk	5 m from trunk	1 m from trunk	2 m from trunk	2 m from trunk	3 m from trunk	5 m from trunk	1 m from trunk	2 m from trunk	2 m from trunk	3 m from trunk	5 m from trunk	1 m from trunk	2 m from trunk	2 m from trunk	3 m from trunk	5 m from trunk	1 m from trunk	2 m from trunk
Mango + Guava + Lemon	16.07 ± 1.36	43.36 ± 5.86	100.00 ± 0.00	34.14 ± 2.17	80.35 ± 12.35	16.28 ± 2.11	46.18 ± 7.21	100.00 ± 0.00	33.65 ± 2.94	68.18 ± 10.69	14.21 ± 1.21	36.64 ± 5.39	100.00 ± 0.00	32.19 ± 3.64	48.34 ± 7.69	14.56 ± 0.93	33.69 ± 5.19	99.28 ±7.32	32.19 ± 3.19	49.34 ± 7.63	14.48 ± 1.38	32.36 ± 4.86	94.36 ± 8.36	32.21 ± 2.94	52.18 ± 7.39
Mango + Guava + Paddy	14.75 ± 1.19	48.92 ± 6.17	100.00 ± 0.00	19.08 ± 1.38	69.30 ± 12.39	15.17 ± 1.63	48.11 ± 6.94	100.00 ± 0.00	19.64 ± 1.32	49.11 ± 8.29	14.82 ± 1.36	42.18 ± 6.43	100.00 ± 0.00	21.36 ± 2.49	42.62 ± 6.11	15.28 ± 1.21	39.64 ± 6.21	100.00 ±0.00	21.36 ± 1.84	43.26 ± 6.48	13.29 ± 1.10	36.51 ± 4.39	97.62 ± 10.11	18.00 ± 2.86	45.00 ± 6.17
Mango + Gamhar	16.82 ± 0.87	42.45 ± 6.39	100.00 ± 0.00	31.51 ± 2.14	99.62 ± 20.31	16.37 ± 1.29	41.63 ± 6.39	100.00 ± 0.00	26.51 ± 2.11	82.16 ± 13.18	15.36 ± 1.29	38.39 ± 5.92	100.00 ± 0.00	25.61 ± 3.17	50.14 ± 7.83	15.39 ± 1.46	34.63 ± 4.86	82.69 ± 7.69	25.61 ± 1.63	56.38 ± 9.31	15.16 ± 1.26	31.68 ± 4.97	83.64 ± 8.17	29.73 ± 2.51	64.69 ± 6.39
Mango + No filler	15.89 ± 1.49	45.11 ± 6.21	100.00 ± 0.00			15.92 ± 1.83	45.87 ± 7.16	100.00 ± 0.00			14.21 ± 0.96	36.71 ± 5.11	100.00 ± 0.00			13.92 ± 0.81	35.18 ± 5.34	100.00 ±0.00			14.32 ± 1.19	33.67 ± 4.11	98.17 ± 7.39		

Table 3 Soil properties under different agri-horti systems of 10 years age

	0-30 cm soil depth					30-60 cm soil depth				
	Guava	Lime	Gamhar	No filler	Average	Guava	Lime	Gamhar	No filler	Average
Organic carbon (%)										
Cowpea	0.52±0.08^{d}	0.58±0.07^{b}	0.61±0.08^{b}	0.54±0.07^{c}	0.57±0.07^{x}	0.36±0.05^{c}	0.33±0.04^{c}	0.42±0.07^{b}	0.32±0.05^{d}	0.36 ±0.05^{x}
French bean	0.53±0.07^{c}	0.52±0.08^{d}	0.66±0.08^{a}	0.52±0.07^{d}	0.56±0.07^{x}	0.36±0.06^{c}	0.35±0.06^{c}	0.40±0.07^{b}	0.34±0.05^{c}	0.36± 0.07^{x}
Paddy	0.63±0.08^{a}	0.59±0.09^{b}	0.61±0.09^{b}	0.56±0.09^{c}	0.60±0.11^{x}	0.32±0.06^{d}	0.31±0.05^{d}	0.47±0.07^{a}	0.32±0.06^{d}	0.36±0.07^{x}
Stylosanthes	0.58±0.09^{b}	0.55±0.09^{c}	0.57±0.09^{b}	0.62±0.09^{a}	0.58±0.09^{x}	0.37±0.05^{c}	0.33±0.05^{c}	0.42±0.06^{b}	0.33±0.05^{c}	0.36±0.08^{x}
Fallow	0.56±0.07^{c}	0.55±0.08^{c}	0.59±0.11^{b}	0.55±0.08^{c}	0.56±0.07^{x}	0.33±0.07^{c}	0.34±0.06^{c}	0.38±0.08^{b}	0.34±0.05^{c}	0.35±0.07^{x}
Average	0.57±0.08^{p}	0.56±0.08^{p}	0.61±0.09^{p}	0.56±0.08^{p}		0.35±0.06^{q}	0.33±0.05^{q}	0.42±0.07^{p}	0.33±0.05^{q}	
Available nitrogen (kg/ha)										
Cowpea	119.21±21.3^{c}	128.63±21.1^{b}	120.64±14.9^{c}	130.69±28.6^{b}	124.79±21.3^{y}	108.46±18.6^{a}	114.68±19.4^{a}	119.43±21.6^{a}	118.61±19.3^{a}	115.30±17.1^{x}
French bean	128.48±24.7^{b}	141.19±22.3^{a}	154.63±24.6^{a}	148.14±21.7^{a}	143.11±19.8^{x}	119.64±18.6^{a}	128.61±20.3^{a}	131.38±21.2^{a}	138.61±19.8^{a}	129.56±20.3^{x}
Paddy	101.63±16.1^{d}	124.69±18.4^{c}	123.14±19.2^{c}	110.36±16.8^{d}	114.96±16.3^{y}	119.49±12.4^{a}	112.63±16.6^{a}	119.61±18.7^{a}	114.49±14.7^{a}	116.56±16.1^{x}
Stylosanthes	122.16±19.4^{c}	141.36±12.6^{a}	136.92±18.3^{b}	129.14±18.2^{b}	132.40±19.6^{x}	109.37±15.4^{a}	120.61±19.3^{a}	119.31±18.4^{a}	120.32±18.1^{a}	117.40±17.6^{x}
Fallow	129.63±19.4^{b}	146.51±21.3^{a}	149.36±21.6^{a}	140.39±22.4^{a}	141.47±20.3^{x}	124.61±21.8^{a}	125.66±18.1^{a}	133.61±19.7^{a}	132.19±19.4^{a}	129.02±19.7^{x}
Average	120.22±17.7^{q}	136.48±20.4^{p}	136.94±20.7^{p}	131.74±18.6^{p}		111.51±16.6^{q}	118.84±17.3^{p}	124.67±18.1^{p}	123.24±18.6^{p}	
Available phosphorus (kg/ha)										
Cowpea	20.29±3.61^{b}	24.11±4.23^{b}	16.11±2.87^{c}	25.36±4.21^{a}	21.47±3.84^{y}	8.21±1.41^{a}	7.11±1.48^{a}	6.11±1.17^{b}	12.61±1.94^{a}	8.51±1.34^{x}
French bean	23.29±3.32^{b}	25.16±3.86^{a}	19.11±3.08^{b}	25.31±3.86^{a}	23.22±3.35^{x}	9.34±1.28^{a}	10.31±1.53^{a}	11.64±1.49^{a}	12.64±1.86^{a}	10.98±1.48^{x}
Paddy	20.67±3.27^{b}	21.31±3.29^{b}	20.31±2.96^{b}	20.64±4.11^{b}	20.73±3.18^{y}	12.34±1.76^{a}	11.69±1.62^{a}	10.38±1.53^{a}	8.18±1.26^{a}	10.65±1.61^{x}
Stylosanthes	25.24±4.38^{a}	22.34±3.41^{b}	26.94±4.13^{a}	29.11±4.26^{a}	25.91±3.85^{x}	10.32±1.63^{a}	12.65±1.87^{a}	8.64±1.24^{a}	12.16±1.74^{a}	10.94±1.63^{x}
Fallow	29.31±4.86^{a}	28.64±4.11^{a}	21.22±3.22^{b}	33.14±4.61^{a}	28.08±3.89^{x}	8.46±1.19^{a}	10.33±1.44^{a}	8.95±1.41^{a}	9.19±1.21^{a}	9.23±1.44^{x}
Average	23.76±3.83^{p}	24.31±3.37^{p}	20.74±3.49^{p}	26.71±3.78^{p}		9.73±1.49^{p}	10.42±1.59^{p}	9.14±1.38^{p}	10.96±1.42^{p}	
Available potassium (kg/ha)										
Cowpea	224.64±23.4^{d}	208.16±28.2^{d}	189.64±27.1^{e}	316.59±37.9^{a}	234.76±33.4^{x}	163.19±24.1^{d}	189.64±25.4^{c}	143.87±18.6^{e}	236.11±26.9^{a}	183.20±23.8^{x}
French bean	253.67±19.8^{c}	249.18±34.9^{c}	194.61±31.4^{e}	289.41±39.4^{a}	246.72±31.9^{x}	201.91±30.8^{c}	204.63±26.7^{c}	167.19±29.1^{d}	211.16±28.1^{b}	196.22±29.4^{x}
Paddy	178.64±22.9^{e}	184.69±28.5^{e}	209.64±31.6^{d}	264.36±32.9^{b}	209.33±31.1^{y}	163.64±21.7^{d}	182.19±26.4^{d}	178.33±28.3^{d}	211.4±31.4^{b}	183.90±28.1^{x}
Stylosanthes	237.85±31.1^{c}	249.64±36.8^{c}	218.37±28.4^{d}	241.61±23.7^{c}	236.87±28.1^{x}	206.32±28.1^{c}	168.16±22.6^{d}	157.67±24.1^{d}	209.11±31.1^{c}	185.32±26.4^{x}
Fallow	259.64±34.8^{b}	231.63±31.9^{c}	236.68±29.4^{c}	240.11±28.4^{c}	242.02±33.0^{x}	199.64±31.2^{c}	193.98±31.4^{c}	208.16±28.3^{c}	219.16±28.4^{a}	205.24±30.2^{x}
Average	230.89±29.6^{q}	224.66±31.9^{q}	209.79±30.8^{q}	270.42±33.2^{p}		186.94±27.3^{p}	187.72±25.8^{p}	171.04±26.8^{q}	217.39±29.1^{p}	

Gamhar + Paddy (0.47±0.07%). The litter fall from the trees might have played a significant role in improving the soil organic carbon content. Murovhi *et al*. (2012) observed total leaf litter addition to the soil by mango (6.3 t/ha), avocado (8.3 t/ha) and litchi (5.6 t/ha) at the tree age of 12–13 years has not only improved soil health but also soil moisture retention capacity.

The available nitrogen content also differed under different treatments. In 0-30 cm soil layer, significantly lower value was recorded in case of guava as filler crop (120.2±17.7 kg/ha) while the contents were at par in case of other three filler crops. With respect to intercrops, significantly lower content was recorded in case of paddy and cowpea while the other treatments were at par. With respect to interaction between filler plants × intercrops, the maximum available nitrogen was recorded in case of Mango + Gamhar + French bean (154.63±24.6 kg/ha). Swain (2014) also reported significant increase in the available nitrogen in the soil in Mango + Guava + French bean under Eastern Ghat highland zones of Odisha. The minimum value in 0-30 cm soil layer was recorded in case of Mango + Guava + Paddy (101.63±16.1 kg/ha). In the 30-60 cm soil depth, significant effects of the filler plants were recorded only and among the filler plants, significantly lower value was recorded in case of guava (111.51±16.6 kg/ha). The higher rate of nutrient uptake by guava due to its higher productivity might have contributed towards the nitrogen removal from the soil. Mishra (2014) reported fruits of guava tree removes high amount of N, P and K from the soil. Hence, this warrants for higher rate of nitrogen application under Mango + Guava + Paddy agri-horticultural system.

Significant effects of the treatments were recorded on available phosphorus content in the 0-30 cm soil depth, whereas in the 0-60 cm depth, the treatmental effects were non-significant. Among the intercrops, lower phosphorus content was recorded in cowpea and paddy. In 0-30 cm soil layer, the phosphorus content did not differ significantly under different filler plants. However, the interaction between filler plants × intercrops was significant and the maximum available phosphorus was recorded in Mango+No filler+fallow (33.14±4.61 kg/ha). The minimum value was recorded in case of Mango+Gamhar+Cowpea (20.29±3.61 kg/ha). Although previous studies with experimental duration of 2-3 years have indicated significant increase in the availability of phosphorus in the mango orchard soils with intercropping of legumes (Swain 2014), the present study clearly indicated depletion in available phosphorus in the soil under different agri-horticultural systems after 10 years of cropping even with recycling of residue. This warrants for regular replenishment of phosphorus in the soil through fertilization.

With respect to available potassium content, significant effects of filler crops, intercrops and their interaction was recorded at both the soil depths. At 0-30 cm soil depth, minimum available potassium was recorded in case of paddy as intercrop (209.33±31.6 kg/ha), whereas the values in other intercrops were at par. The content in case

Table 4 Rice equivalent yield under different mango based multitier agri-horti system

Mango based cropping systems	Rice equivalent yield (t/ha)					Cumulative REY (t/ha)
	2005-06	2006-07	2007-08	2008-09	2009-10	
Mango+ Guava + Cowpea	8.70	3.99	7.05	7.14	7.40	34.28
Mango+ Citrus + Cowpea	13.92	5.57	2.53	2.47	2.35	26.84
Mango+ Gamhar + Cowpea	0.09	0	2.79	2.99	2.01	7.89
Mango+ no filler + Cowpea	0.19	0.96	2.00	1.84	2.25	7.24
Mango+ Guava + Paddy	10.92	8.75	6.88	8.40	8.61	43.56
Mango+ Citrus + Paddy	8.26	0.74	1.14	0.98	2.11	13.22
Mango+ Gamhar + Paddy	0.53	0.64	1.76	1.23	2.00	6.16
Mango+ no filler + Paddy	0.32	0.48	1.63	0.30	2.62	5.35
Mango+ Guava + Stylosanthes	11.11	6.04	7.77	10.60	8.11	43.63
Mango+ Citrus + Stylosanthes	4.12	4.72	0.57	2.11	2.65	14.18
Mango+ Gamhar + Stylosanthes	0.01	0.00	1.32	0.41	1.91	3.64
Mango+ no filler + Stylosanthes	0.00	0.00	0.90	0.41	1.62	2.94
Mango+ Guava + French bean	14.69	10.14	8.73	9.52	8.16	51.24
Mango+ Citrus + French bean	8.37	2.40	2.76	6.23	2.56	22.32
Mango+ Gamhar +F rench bean	4.33	0.96	2.64	2.76	2.11	12.80
Mango+no filler + French bean	3.92	0.29	3.02	0.59	2.30	10.11
Mango+ Guava + Fallow	11.44	5.12	4.78	7.12	7.23	35.69
Mango+ Citrus + Fallow	6.43	1.06	0.90	3.07	2.39	13.84
Mango+ Gamhar + Fallow	0.00	0.00	0.74	1.76	2.16	4.66
Mango+ no filler + Fallow	0.00	0.00	0.42	0.64	2.00	3.06
SEm±	1.43	1.12	1.48	1.19	1.13	5.41
CD (P=0.05)	4.31	3.27	4.39	3.55	3.29	16.41

of all the filler crops were significantly lower than that in case of no filler (270.42±33.2 kg/ha). Among the different combinations of filler plant and intercrops, the maximum content was recorded in case of Mango+No filler+Cowpea (316.59±37.9 kg/ha) which was at par with Mango + No filler + French bean. The minimum content was recorded in case of Mango + Guava + Paddy (178.64±22.9 kg/ha). At 30-60 cm soil depth, the minimum available potassium in the soil was recorded in case of Gamhar (171.04±26.8 kg/ha), whereas the content did not differ significantly among the other filler plants. Among the different combinations, the maximum available potassium was recorded in case of Mango + No filler + Cowpea (236.11±26.9 kg/ha), whereas the minimum value was recorded in case of Mango + Gamhar + Cowpea (143.87±18.6 kg/ha). Hence, the depletion in the available potassium can be attributed to higher uptake by the filler plants. Tiwari and Baghel (2014) also reported depletion of phosphorus and potassium in mango orchard soils due to growing of leguminous intercrops.

Yield

Data on total rice equivalent yield (REY) during different years is given in Table 4. During all the five years, the maximum REY was recorded in case of Mango + Guava + French bean. Among all the agri-horti systems, the highest cumulative rice equivalent yield was recorded in case of Mango + Guava + French bean which was at par with other agri-horti systems like Mango + Guava + Stylosanthes, Mango + Guava + Fallow and Mango + Guava + Paddy. During all the five years, the significantly higher REY was recorded in case of agri-horti systems with either guava as filler crop or French bean as intercrop. In another study, Swain (2014) recorded highest Land Equivalent Ratio in case of Mango + Guava + Cowpea and Mango + Guava + French Bean.

With respect to cumulative yield of mango, the effect of intercrops was non-significant, whereas significant effect of filler plants was recorded (Table 5). The maximum yield of mango was recorded with guava as filler plant. With respect to interaction between Filler plant × Intercrops, the maximum yield of mango was recorded in case of Mango + Guava + Stylosanthes which was at par with Mango + Guava + Paddy and Mango + Guava + French bean.

Table 5 Cumulative yield of mango under different agri-horticultural systems (2005-10)

Intercrops	Filler plants				Average (Inter crops)
	Guava	Lime	Gamhar	No filler	
Cowpea	32.4± 3.61^{c}	28.46± 4.18^{d}	28.42± 3.93^{d}	29.13± 3.82^{d}	29.60± 3.91^{x}
French bean	48.14± 5.22^{a}	38.62± 4.63^{b}	34.78± 4.19^{c}	32.19± 4.61^{c}	38.43± 4.83^{x}
Paddy	51.32± 5.93^{a}	30.38± 4.62^{c}	30.19± 4.43^{c}	30.13± 4.18^{c}	35.50± 4.69^{x}
Stylosanthes	55.31± 4.64^{a}	48.28± 4.39^{a}	25.12± 4.21^{d}	20.11± 3.11^{e}	37.20± 4.31^{x}
Fallow	43.22± 4.29^{b}	41.49± 5.79^{b}	32.19± 4.27^{c}	25.19± 3.74^{d}	35.52± 4.49^{x}
Average (Filler plants)	46.07± 4.76^{p}	37.44± 4.61^{q}	30.14± 4.32^{q}	27.35± 3.94^{q}	

Table 6 Cumulative yield of filler plants under different agri-horticultural systems (2005-10)

Intercrops	Yield of guava (kg/tree)	Yield of lemon (kg/tree)	Yield of gamhar (m^3)
Cowpea	56.12±6.93^{b}	44.8±7.77^{m}	2.24±0.36^{q}
French bean	64.18±8.18^{b}	38.11±6.91^{m}	3.75±0.53^{p}
Paddy	81.4±8.41^{a}	20.16±2.69^{n}	3.73±0.41^{p}
Stylosanthes	95.31±10.16^{a}	20.16±3.55^{n}	3.37±0.53^{p}
Fallow	79.63±12.39^{a}	21.48±3.93^{n}	3.03±0.48^{p}

Cumulative yield of filler plants were significantly influenced by intercropping (Table 6). The maximum yield of guava was recorded in case of intercropping of stylosanthes which was at par with that of paddy and fallow. In case of lemon, significantly higher yields were recorded in case of cowpea and French bean. In case of gamhar, significantly lower yield (tree volume) was recorded in case of cowpea intercropping.

The cumulative yield (2005-2010) of different intercrops varied significantly under different agri-horticultural systems. As evident from the figure, the yields of all the intercrops were significantly higher under Mango + Guava. This indicated possible role of leaf fall from guava in favouring soil moisture regime and microclimate under Mango + Guava during 6th to 10th year of orchard establishment since significant reduction in available nutrient was also recorded under Mango + Guava. Rathore *et al.* (2013) have also recorded significant increase in soil moisture content under different mango based agri-horticultural models in rainfed situations of western Himalaya. Again, the light intensity below the tree canopy of Mango + Guava plants was higher than that under Mango + Lemon. Favourable light profile might have partially contributed towards the higher yield of intercrop under guava trees.

Hence, the study clearly indicated the significance of guava as filler plant for increasing the economic yield of mango based agri-horticultural system. Based on 10 years of data, Mango + Guava + French bean was found to be the most effective agri-horticultural system under rainfed conditions of eastern plateau and hill conditions. However, the study also indicated the need for additional supplementation of nitrogen and potassium for maintaining the soil fertility.

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