

Effect of Intercropping on Soil Health and Yield Potential of Mango in Paradise Valley, East Kawlchaw, Saiha District of Mizoram, NE India

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ABSTRACT

The effect of different intercrops on soil nutrient status, yield of mango and its biological efficiency was studied, during 2008-2013, in 10 year-old mango orchards planted at 8m x 8m spacing, in Paradise valley, East Kalcho, Saiha district of Mizoram. The intercrops in mango orchard were ginger, French bean, paddy, turmeric, roselle and maize. The results indicate that the average fruit weight was significantly higher ($P < 0.005$) in intercrops than the sole mango crop and the average fruit weight was maximum in mango+roselle+French bean followed by mango+cowpea. The number of fruits/tree varied from 68 to 130 in different treatments. The average mango yield was higher in the intercropping systems than sole mango crop; it varied between intercrops and years, ranging from 1.89 Mg/ha (mango + pineapple) to 4.84 Mg/ha (mango + roselle + French bean). Intercropping improved the soil health by enhancing available nitrogen at 0-15 cm depth by 17.53% (mango + turmeric) to 37.64% (Mango + roselle + French bean) compared to the sole mango. Intercropping also increased the available phosphorus and potassium contents both at 0-15 and 0-30 cm soil depths. The mean mango equivalent yield was highest (6.83 Mg ha^{-1}) in Mango+pineapple followed by Mango+roselle+French bean (6.33 Mg ha^{-1}), Mango+cowpea (6.08 Mg ha^{-1}) to sole mango (1.78 Mg ha^{-1}). The Land Equivalent Ratio was always higher in intercropping than the sole mango and it ranged from 2.06 (Mango+pineapple) to 3.53 (Mango+cowpea). Thus, intercropping not only improved soil nutrients but also resulted in higher yield of the fruit crop.

Key Words: Intercropping; Land Equivalent Ratio; Mango Equivalent; Soil Health.

INTRODUCTION

Mango is one of the most important fruit crops in the tropical and subtropical lowlands. It is native to India, Bangladesh, Myanmar and Malaysia, but can be found growing in more than 60 other countries throughout the world. Kawl-thei or Kalcho Mango (*Mangifera indica* Linn.) is the leading fruit crop of Paradise Valley in East Kalcho, Saiha. This valley is known for this variety of mango because of its delicious taste. The plant is dwarf and vigorous with regular fruit bearing. The mango orchard is 10 years old wherein the plants are spaced at 8m x 8m (144 mature fruit bearing trees per hectare). Since no plant protection measures (except dusting of ash as a traditional knowledge) are carried out, mango grown in the Paradise Valley of the state are prone to

mealy bug, fog and cloudy weather at the time of flowering from November to February also result in poor setting of fruits and favours the pest attack and diseases. In order to reduce the mealy bug problem, the farmers were trained to carry out banding of trunk in the month of November-December with slippery bands of polythene sheet, often mixed with grease and coal tar, besides they are trained in digging of the soil around the mango trunk during the hot summer months and clear weeds. There is nevertheless a good scope for increasing the area and income generation through mango in the state. The productivity of rainfed uplands especially in the hilly north eastern region is comparatively low but a majority of the farmers depend on it for their sustenance. The shifting cultivation which is primitive in nature and tended to be denigrated as being wasteful and inefficient

because of the low crop yields and potential decline of soil productivity is still widely practiced by the people of the state. Under these circumstances the objective is to increase the production and productivity of the rainfed upland by raising more than one crop per unit time in the same piece of land.

Horticulture based cropping systems are essential for efficient utilization of natural resources and to the requirement of farmers without deteriorating the land productivity and to stabilize income (Sahoo 2007). These systems support plants with various morpho-phenological features to maximize natural resource use efficiency and enhanced total factor productivity (Sharma and Choudhury 2002) thus enabling them to be self sustainable where solar energy can be harvested at different heights, soil resources can be efficiently used and cropping intensity be increased. Several workers (Nair 1984, Nair et al. 1995) recommended growing of certain vegetable crop in horti-based agroecosystems for better utilization of land, light and water. Some authors have also found that multiple cropping in mango orchard gives an extra income in addition to higher yield (Singh et al. 1996, Rath and Swain 2006, Rathore et al. 2013). Intercropping between mango trees with annual crops during early years of orchard development has been found to be very beneficial to both the crops (Szott et al. 1991, Palm 1995). High density multiple cropping provide synergetic effect on soil productivity an yield of tree crop and thus in optimum utilization of land (Sharma and Choudhury 2002) and stabilizing crop yield (Sahoo et al. 2015). Cultivation of various intercrops under mango under rain fed conditions have received some attention elsewhere (Rath and Swain 2006, Ali et al. 2008, Abouziena et al. 2010, Bari and Rahim 2010, Nayak et al. 2014)

In order to utilize the land maximally, the farmers at Paradise Valley have been growing a number of crops in the interspaces between mango trees but these intercrops are not grown systematically and no proper package and practice of intercrops are followed. Farmers often grow the crops randomly in the interspaces and of course, according to their wisdom to fetch maximum return. There is practically no information available on the effect of intercrops on the yield of the main fruit mango crop and soil health in these ecosystems. Keeping in view of the importance of various intercrops grown in mango orchards, it was felt necessary to evaluate the effect of some of the intercrops on soil health, yield and biological efficiency of mango.

MATERIALS AND METHODS

Study Site

The experiment was conducted in 10-year-old mango orchards located at Paradise Valley, East Kalcho village 22° 24' 05" N, 92° 57' 23" E, 177 m altitude) in Saiha district of Mizoram spread over an area of about 500 ha. The experiment was conducted under National Agricultural Innovation Project during 2008-2013. Mango being a popular fruit crop in the site and grown widely by the farmers, it was felt necessary to scientifically introduce various food crops as intercrops in between the fruit trees to ensure food security and additional income generation. The average temperature during winter in study site varied from 7 to 21°C and in summer, it varied from 28 to 35°C with 78% relative humidity and annual rainfall of 2560 mm (based on the data from the last five years). The climate of the study site is hot and dry. The soil of the experimental site is sandy loam with pH varying from 5.30-5.85.

Experimental Design

Since the mango growers had not been making proper use of the spaces available between the mango trees, various intercrops like cow pea (*Vigna unguiculata* L. Walp), ginger (*Zingiber officinale* Roscoe), turmeric (*Curcuma longa* L.), French bean (*Phaseolus vulgaris* L.), pineapple (*Ananas comosus* (L.) Merr.), paddy (*Oryza sativa* L.), maize (*Zea mays* L.) and roselle (*Hibiscus sabdariffa* L.) were introduced systematically not only to maximally utilize the land but also to increase farm income. The experiment was conducted before the onset of rainy season. Prior to this the land between the interspaces of mango trees was cleared of weeds, and prepared for sowing of intercrops. The crops were sown 1.5 m away from the mango tree and recommended agronomic practices for all the intercrops were followed throughout their growing period. Sole mango tree plots also received identical weed management as mixed cropping plots. The effect of eight intercrops on main mango crop was studied in small plots (15m x 15m) replicated thrice, using simple RBD by accommodating two mango bearing trees in each plot. As the filler crops were not systematically spaced and uniform, the plots having mango and filler crops were not considered. The effect of intercrop was compared from three control plots of same size occupying two fruit bearing mango trees. All the plots were given similar agronomic treatment,

raised purely on organic condition; farmyard manure was applied @ 20 Mg ha⁻¹, weeding was carried out by hand, the intercrops were raised under rainfed condition. The main crop was sprinkled when felt necessary during fruit bearing stage and similar treatment was given to all the plots.

The soil samples were collected randomly from five different places in each plot at a two soil depths (0-15 cm and 15-30 cm), mixed thoroughly and bulked, for each depth separately and a representative soil sample was drawn for analysis of organic carbon, available nitrogen, phosphorus and potassium. The soil organic carbon was determined by Walkley and Black (1934) method, available nitrogen was determined by the method as suggested by Subbiah and Asija (1956). Available phosphorus was determined by Bray and Kurtz (1945) method and available potassium was estimated by Page et al. (1982).

The yield potential of mango based intercropping was determined by calculating Land Equivalent Ratio (LER) as suggested by Rao and Coe (1992).

$$LER = Y_i^1/Y_s^1 + Y_i^2/Y_s^2 + Y_i^3/Y_s^3 + \dots + Y_i^n/Y_s^n$$

where Y = yield of a component (tree/crop);

Subscripts s and i indicate sole and intercrop yields respectively;

Superscripts (1, 2, 3...n) indicate the component in the system

When LER is unity (=1) there is no additional production advantage of mixed culture; when LER is less than unity, there is disadvantage and when LER is more than unity, there is advantage of mixed culture.

Economic valuation of mango based intercropping was calculated using measured yields for each crop component and the prevailing market price in INR during 2012 and Mango Equivalent Yield (MEY) was calculated as per Swain (2014):

$$MEY = \text{Yield of mango} + \left[\frac{\text{Yield of intercrop} \times \text{price of intercrop (Rs kg}^{-1}\text{)}}{\text{Price of main mango crop (Rs kg}^{-1}\text{)}} \right]$$

RESULTS

Effect of Intercropping on Soil Health

The results show that intercropping affected the physico-chemical properties of the soil and most of the soil

parameters improved in the inter-cropping systems over sole mango crop (control treatment). The soil pH ranged from 5.30 to 5.85 and in general it was relatively higher in intercropped system than the sole mango crop at both 0-15 and 15-30 cm soil depths (Table 1). The soil organic matter (SOM) also was higher in the intercropping systems than in the sole mango crop and it ranged from 0.76% (control) to 0.98% in intercropping system with roselle and French bean. In cowpea intercrops, SOM increased by 20.25% over the control. The available nitrogen content in the soil was maximum (410.9 kg ha⁻¹) in the system intercropped with roselle and French bean, followed by cowpea (405.8 kg ha⁻¹) and minimum in control (285.6 kg ha⁻¹). Similar was the case with the available potassium which ranged from 342.6.2 kg ha⁻¹ to 404.7 kg ha⁻¹ and increased from 4.52 % (pineapple) to 17.24% in roselle with French bean at 0-15 cm soil depth (Table 1). The available phosphorus in the intercropping system was in the order of roselle with French bean > cowpea > ginger > turmeric > maize > pineapple > roselle > paddy and lowest in the control treatment (Table 2). The values of available nitrogen, potassium and phosphorus were more or less similar between cow pea and French bean intercropping systems and were significantly (P<0.05) higher when compared with the sole mango crop. Among the other intercrops paddy and maize showed higher values of available nitrogen and available potassium over the systems intercropped with ginger and turmeric. The results reveal the mango + cowpea and mango+roselle+ French bean systems improved organic matter, available nitrogen, phosphorus, potash contents and both intercropping treatments and soil depth significantly (P<0.005) affected the chemical properties of the soil (Table 6).

Effect of Intercropping on Fruit Yield of Mango

Intercropping affected the reproductive yield traits of the main mango crop. The number of fruits per tree in the different intercropping systems varied widely and ranged from 68 (control) to 130 (roselle with French bean) and in the other intercropping systems, it was in the order of cowpea > maize > ginger/turmeric > roselle/ paddy > pineapple. Similarly, the weight of the mango fruit in the intercropping systems too was influenced significantly (P<0.05) by intercrops. The average mango weight varied between 165g to 300g (Table 2). The variation in mango weight between roselle and paddy systems was fairly similar, so also between turmeric and ginger systems. The mango weight was comparably similar in

Table 1. Effect of intercropping on nutrient status of soil in mango orchard at Paradise Valley, East Kawlchaw, Saiha district of Mizoram, North-East India

Treatment	Soil pH		SOM (%)		Available N (kg ha ⁻¹)		Available P ₂ O ₅ (kg ha ⁻¹)		Available K ₂ O (kg ha ⁻¹)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Mango - sole crop	5.42 ±0.03	5.3 ±0.15	0.79 ±0.01	0.76 ±0.01	298.5 ±7.40	285.6 ±1.51	15.5 ±0.68	15.2 ±0.31	345.2 ±2.52	342.6 ±1.06
Mango + pineapple	5.76 ±0.04	5.6 ±0.06	0.83 ±0.02	0.8 ±0.09	340.4 ±2.56	330.7 ±3.65	15.9 ±0.36	15.7 ±0.06	360.8 ±1.25	355.4 ±1.82
Mango + cowpea	5.64 ±0.02	5.5 ±0.00	0.95 ±0.01	0.92 ±0.01	405.8 ±3.24	385.7 ±3.25	17.7 ±0.12	17.3 ±0.12	400.2 ±0.81	394.6 ±2.32
Mango + turmeric	5.48 ±0.07	5.45 ±0.06	0.87 ±0.01	0.83 ±0.02	350.3 ±1.39	343.8 ±0.53	16.2 ±0.15	16 ±0.23	370.6 ±1.80	368.2 ±1.10
Mango + ginger	5.6 ±0.06	5.5 ±0.06	0.87 ±0.02	0.87 ±0.01	345.2 ±1.29	340.2 ±1.25	16.4 ±0.12	16.2 ±0.31	374.2 ±2.08	354.2 ±1.17
Mango + maize	5.7 ±0.10	5.7 ±0.13	0.87 ±0.01	0.84 ±0.01	360.4 ±2.97	357.4 ±1.37	16 ±0.12	16 ±0.95	370.6 ±3.60	360.6 ±2.95
Mango + roselle	5.49 ±0.11	5.42 ±0.08	0.82 ±0.02	0.8 ±0.01	375.4 ±3.43	363.6 ±0.67	15.8 ±0.12	15.2 ±0.23	380.5 ±1.21	362.8 ±2.31
Mango + paddy	5.81 ±0.02	5.7 ±0.06	0.86 ±0.02	0.86 ±0.02	380.8 ±3.99	370.6 ±1.10	15.7 ±0.06	15.2 ±0.29	385.8 ±3.05	372.4 ±1.15
Mango + roselle + french bean	5.85 ±0.03	5.6 ±0.06	0.98 ±0.01	0.95 ±0.03	410.9 ±1.19	400.2 ±0.92	18.6 ±0.17	18.2 ±0.12	404.7 ±5.42	392.8 ±2.42
LSD P< 0.05	0.21	0.29	0.04	0.11	12.27	6.56	0.97	1.32	9.59	6.68

Values are pooled means of five years 2008-2013 ± SEM, n=15.

Table 2. Effect of intercropping on average fruit weight and number of fruits/tree in mango orchard at Paradise Valley, East Kawlchaw, Saiha district of Mizoram, North-East India

Treatment	Average fruit weight g					LSD	Number of fruits tree ⁻¹					LSD
	08-09	09-10	10-11	11-12	12-13		08-09	09-10	10-11	11-12	12-13	
Mango sole crop	170 ±2.52	160 ±10.41	165 ±2.52	160 ±8.74	155 ±1.73	23.58	84 ±4.58	70 ±2.00	68 ±1.15	90 ±1.15	68 ±1.53	9.12
Mango + pineapple	172 ±1.00	165 ±5.13	170 ±3.06	170 ±3.06	160 ±2.00	11.78	84 ±2.00	82 ±2.08	80 ±1.15	95 ±3.21	82 ±1.73	7.99
Mango + cowpea	280 ±3.61	263 ±7.09	290 ±2.52	290 ±2.89	260 ±2.00	15.08	122 ±8.08	115 ±3.61	110 ±2.31	125 ±4.58	105 ±1.00	17.12
Mango + turmeric	210 ±11.24	200 ±7.64	210 ±7.64	207 ±1.00	265 ±1.53	26.14	92 ±4.16	90 ±2.00	80 ±1.15	95 ±0.00	78 ±1.15	8.16
Mango + ginger	220 ±4.04	200 ±2.52	205 ±9.61	200 ±5.77	190 ±3.61	21.16	92 ±2.31	90 ±2.00	90 ±2.00	95 ±3.00	74 ±1.53	8.27
Mango + maize	230 ±6.93	212 ±4.16	216 ±4.93	225 ±4.04	210 ±10.07	23.99	97 ±1.53	95 ±1.53	95 ±1.15	100 ±2.00	87 ±1.00	5.52
Mango + roselle	225 ±5.29	214 ±11.59	220 ±14.36	216 ±2.00	210 ±10.26	36.42	90 ±3.61	85 ±1.53	80 ±3.06	98 ±1.15	80 ±2.52	9.47
Mango + paddy	225 ±2.89	215 ±4.04	220 ±6.11	210 ±1.53	210 ±10.41	21.89	90 ±2.31	85 ±1.53	85 ±1.73	100 ±1.15	86 ±0.58	5.85
Mango + roselle + french bean	280 ±5.00	275 ±2.89	300 ±3.61	285 ±3.21	270 ±2.89	13.43	120 ±3.06	100 ±2.00	105 ±2.52	130 ±1.53	100 ±1.15	8.05
LSD P< 0.05	19.02	23.79	24.55	14.64	21.55		13.78	7.32	6.65	8.20	5.02	

Values are means ± SEM, n=3.

cowpea and roselle+French bean systems. The year-wise variation in weight of the fruit was not significant between the intercropped systems; however, the number of fruits/tree was conspicuously higher ($P<0.05$) during 2011-12 and 2008-09 than other years of study. The average fruit yield of mango was remarkably ($P<0.05$) higher in the intercropped system with roselle+French bean and cowpea when compared with the control. The intercropping systems of roselle and paddy showed a fairly similar result in the average fruit yield per hectare. The yield of mango per hectare was higher during 2008-

09 and 2011-12 while it was fairly similar across other years in a given intercropping system (Table 3).

Effect of Intercropping on Yield of Intercrops

Both the intercrops and year had significant ($P<0.05$) effect on mango yield (Table 6). The MEY was conspicuously different between the intercrops (Figure 1). Among the intercropping systems mango equivalent ranged from 2.67 Mg ha⁻¹ (mango+paddy system during 2012-13) to 7.19 Mg ha⁻¹ (mango+roselle+French bean

Table 3. Average fruit yield in mango orchard in different years at Paradise Valley, East Kawlchaw, Mizoram

Treatment	Average fruit yield, kg ha ⁻¹					LSD
	2008-09	2009-10	2010-11	2011-12	2012-13	
Mango sole crop	2059.49 ±139.89	1617.12 ±142.58	1616.45 ±51.24	2074.27 ±123.08	1518.48 ±50.63	408.82
Mango + pineapple	2080.22 ±44.93	1948.27 ±79.13	1958.59 ±48.71	2327.42 ±111.28	1889.28 ±46.80	264.56
Mango + cowpea	4927.39 ±385.40	4354.42 ±173.05	4592.26 ±68.91	5223.60 ±240.00	3931.78 ±67.97	825.26
Mango + turmeric	2795.52 ±279.68	2596.32 ±158.02	2421.60 ±122.21	2831.76 ±13.68	2976.86 ±57.93	581.03
Mango + ginger	2914.94 ±95.42	2590.56 ±26.20	2654.78 ±119.46	2731.68 ±45.45	2026.22 ±79.56	300.10
Mango + maize	3212.06 ±99.22	2901.22 ±91.54	2955.55 ±87.71	3240.00 ±86.32	2632.03 ±141.66	385.05
Mango + roselle	2915.71 ±131.99	2615.57 ±109.67	2542.37 ±242.67	3048.77 ±61.76	2416.22 ±108.47	536.98
Mango + paddy	2917.92 ±112.24	2629.92 ±16.93	2690.50 ±47.81	3023.62 ±23.27	2602.32 ±146.29	320.90
Mango + roselle + french bean	4836.96 ±122.99	3961.44 ±117.70	4537.01 ±139.57	5335.25 ±89.04	3887.04 ±3.36	395.58
LSD P < 0.05	644.25	393.81	411.24	377.23	309.92	

Values are mean ± SEM, n = 3

Table 4. Mango Equivalent Yield (MEY) and Land equivalent Ratio (LER) of intercropping in different years at mango orchard at Paradise Valley, East Kawlchaw, Saiha district of Mizoram, North-East India

Treatment	MEY (Mg ha ⁻¹)					LER of Intercropping				
	08-09	09-10	10-11	11-12	12-13	08-09	09-10	10-11	11-12	12-13
Mango (sole crop)	2.06	1.62	1.62	2.07	1.52	1	1	1	1	1
Mango + pineapple	7.28	6.55	6.56	7.11	6.68	1.99	2.07	2.07	2.02	2.14
Mango + cowpea	6.81	4.58	6.34	6.99	5.66	3.35	3.72	3.71	3.4	3.45
Mango + turmeric	4.49	5.24	4.14	4.72	4.65	2.38	2.66	2.53	2.51	2.97
Mango + ginger	4.43	3.94	4.17	4.35	3.59	2.38	2.47	2.61	2.35	2.33
Mango + maize	4.25	3.53	3.86	4.12	3.42	2.47	2.66	2.62	2.33	2.42
Mango + roselle	3.27	3.83	2.90	3.36	2.68	2.35	2.67	2.51	2.28	2.27
Mango + paddy	3.80	3.29	2.77	3.10	2.67	2.40	2.56	2.56	2.35	2.43
Mango + roselle + French bean	6.72	5.79	6.35	7.19	5.59	3.34	3.42	3.76	3.54	3.46

system during 2011-12). The mango equivalent between mango+ cowpea, mango+pineapple and mango+ roselle +French bean was significantly higher ($P < 0.05$) than the remaining systems and the relative difference in MEY was also significant ($P < 0.001$) between the inter-crops (Figure 2, Table 6). The Land equivalent ratio (LER) of intercropping did not vary significantly between the years for a given cropping system, however, it varied between intercrops within a given year (Figure 3). The LER was always higher than 1 in all intercrops and ranged from 1.99 (mango+pineapple) to 3.76 (mango + roselle+French bean). The yield reduction in intercrops

varied from 10.0 to 20.0% compared to their respective sole crops (Table 5). However, the main mango crop also facilitated higher yield in turmeric by 5%. The average LER of all intercropping was in the order of cowpea > mango+ roselle+French bean > turmeric > maize > paddy > ginger > roselle > pineapple (Table 5). The average mango equivalent yield was highest (6.83 Mg ha⁻¹) in mango+pineapple followed by mango+roselle+French bean (6.33 Mg ha⁻¹), mango+cowpea (6.07 Mg ha⁻¹) and lowest (3.13 Mg ha⁻¹) in mango+paddy among the intercropping systems (Table 5). There was a remarkable ($P < 0.01$) year wise variation in both LER and MEY values

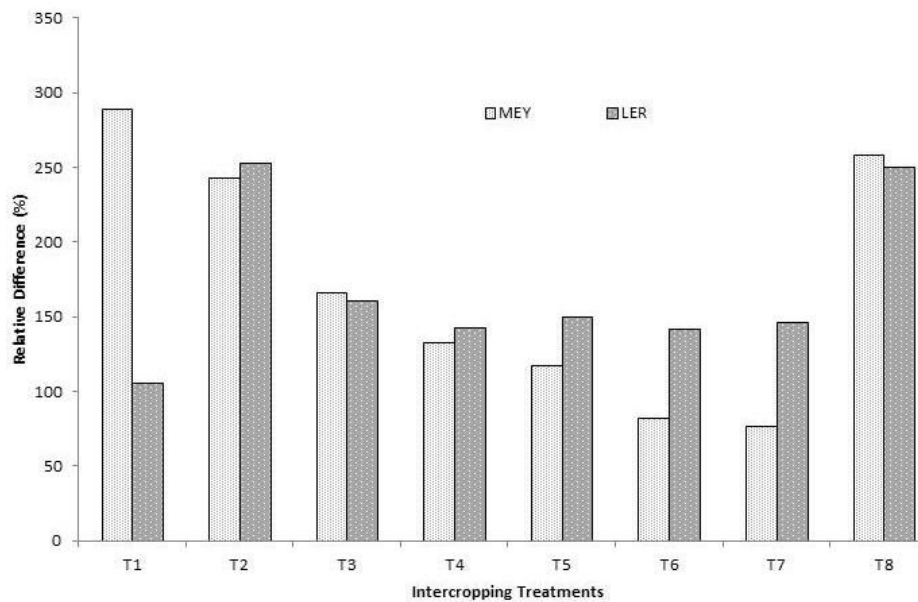


Figure 1. Relative Difference % of increase in MEY and LER of different intercropping treatments from sole mango crop. T1 - Mango+pineapple; T2- Mango+cowpea; T3- Mango+turmeric; T4- Mango+ginger; T5- Mango+maize; T6- Mango+roselle; T7- Mango+paddy; T8- Mango+roselle+french bean

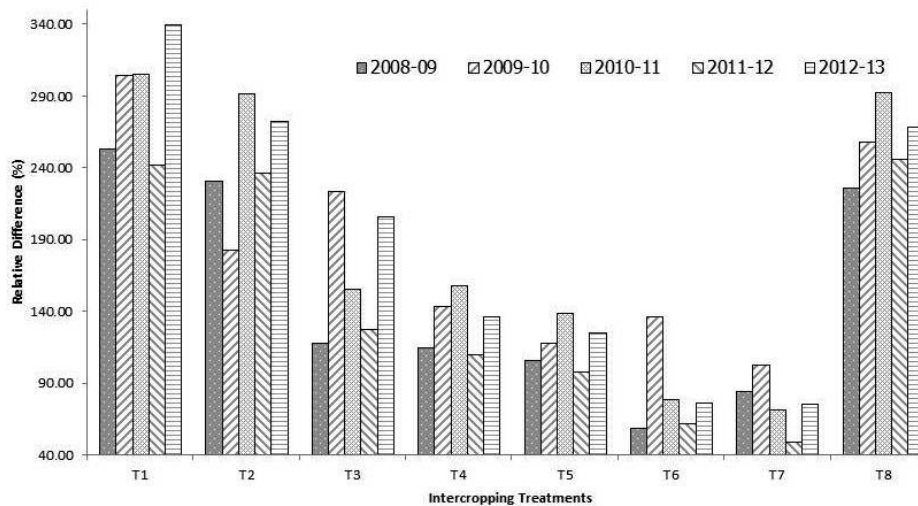


Figure 2. Relative Difference % of increase in MEY of different intercropping treatments from sole mango crop during 2008-2013. T1 to T8 are intercropping treatments as in Figure 1.

among different intercropping systems (Table 4). The mean MEY and mean LER shows highest MEY obtained in intercropping system with French bean and highest LER with intercropping system with turmeric.

DISCUSSION

The practice of intercropping is shown to be beneficial over sole cropping by many workers all over the world.

Since two or more crop species are cultivated on the same physical space during intercropping there are possibilities of getting more benefits in terms of increasing yield, yield stability and improvement in soil fertility (Lithourgidis et al. 2011). Nevertheless the achievement of these benefits relies on the complementary and non-competitive utilization of the growth resources by the intercropped elements in the systems. A significant increase in soil organic matter content, available nitrogen, potassium and phosphorus in the intercropping

Table 5. Mango Equivalent Yield (MEY) and Land equivalent Ratio (LER) in mango orchard at Paradise Valley, East Kawlchaw, Saiha district of Mizoram, North-East India

Treatment	Yield (Mg ha ⁻¹) of components			LER for different components		
	Mango	Intercrop	MEY	Mango	Intercrop	Intercropping
Mango (sole crop)	1.78 ±0.12	0.00 ±0.00	1.78 ±0.12	1.00 ±0.00	0.00 ±0.00	1.00 ±0.00
Mango + pineapple	2.04 ±0.08	7.19 ±0.16	6.83 ±0.15	1.16 ±0.04	0.90 ±0.02	2.06 ±0.03
Mango + cowpea	4.61 ±0.22	1.34 ±0.02	6.08 ±0.44	2.63 ±0.09	0.89 ±0.02	3.53 ±0.08
Mango + turmeric	2.72 ±0.10	0.87 ±0.02	4.65 ±0.18	1.56 ±0.11	1.05 ±0.02	2.61 ±0.10
Mango + ginger	2.58 ±0.15	1.14 ±0.03	4.10 ±0.15	1.46 ±0.07	0.96 ±0.03	2.43 ±0.05
Mango + maize	2.99 ±0.11	1.38 ±0.06	3.84 ±0.16	1.70 ±0.06	0.80 ±0.04	2.50 ±0.06
Mango + roselle	2.71 ±0.12	0.32 ±0.02	3.21 ±0.20	1.57 ±0.07	0.84 ±0.05	2.42 ±0.08
Mango + paddy	2.77 ±0.08	0.16 ±0.01	3.13 ±0.20	1.58 ±0.06	0.88 ±0.04	2.46 ±0.04
Mango + roselle + French bean	4.51 ±0.27	1.36 ±0.02	6.33 ±0.29	2.55 ±0.08	0.95 ±0.02	3.50 ±0.07
LSD (P< 0.05)	0.50	0.20	0.76	0.23	0.10	0.21

Values represent pooled mean of five years (2008-2013), ± SEM, n = 15

Table 6. Analysis of variance ANOVA, 2-ways fixed effects model due to intercropping treatments, soil depths and year on chemical properties of the soil and reproductive traits of main mango fruit

Parameters	Treatment		Soil Depth		Treatment x Depth		Year		Treatment x Year	
	df	F- value	df	F- value	df	F- value	df	F- value	df	F- value
Soil pH	1	9.997**	8	7.219**	8	0.507 ^{ns}	-	-	-	-
Soil Organic Matter	1	4.071*	8	11.889**	8	0.166 ^{ns}	-	-	-	-
Available Nitrogen	1	55.487**	8	288.55**	8	1.549 ^{ns}	-	-	-	-
Available P ₂ O ₅	1	3.881 ^{ns}	8	18.902**	8	0.150 ^{ns}	-	-	-	-
Available K ₂ O	1	76.988**	8	109.46**	8	3.580**	-	-	-	-
Fruit weight	4	6.043**	-	-	-	-	8	227.583**	32	3.849**
Number of Mango tree ⁻¹	4	77.876**	-	-	-	-	8	127.794**	32	2.760**
Mango Yield	4	41.394**	-	-	-	-	8	292.613**	32	2.841**
Intercrop Yield	4	7.125**	-	-	-	-	8	4932.329**	32	3.470**

* significant at p<0.05; ** significant at p<0.005; ns = not significant

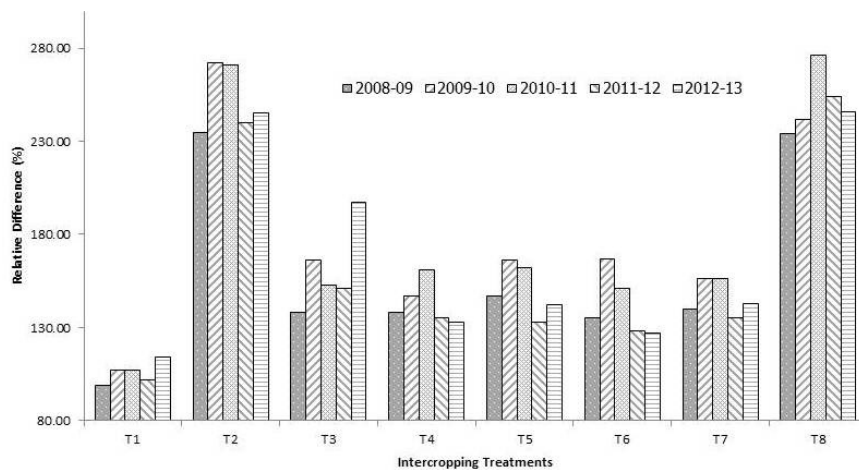


Figure 3. Relative Difference % of increase in LER of different intercropping treatments from sole mango crop during 2008- 2013. T1 to T8 are intercropping treatments as in Figure 1.

systems over the sole main mango crop in the present study obviously was related to the better soil conditions brought by the intercrops. An increase in the soil pH in intercropped systems compared with sole cropping systems reveals that intercropping lead to reduction in soil acidity compared to sole mango cropping systems, due to higher organic material generation in the later than the former. The planting of French bean, cowpea and maize have been able to return sufficient quantities of plant residues to the soil thereby increasing soil organic matter contents. Similar increase in soil organic carbon under intercropping treatments compared to their respective sole crops was reported by Bichel (2013).

Similarly, increase in available nitrogen in the intercropped systems over the sole crop could be due to greater recycling of biomass in the interspaces with higher percentage of nitrogen than the sole crop. Similar arguments have been made by Swain et al. (2012). Among the intercrops significantly higher ($P < 0.05$) increase in available nitrogen in roselle+French bean and cowpea intercropped systems reveal the nitrogen fixing ability of the legumes and when the residues of these intercrops got incorporated into the soil must have added through decomposition resulting into higher nitrogen availability in soil. According to Ghosh (2001) cowpea and French bean have the ability to fix atmospheric nitrogen and increasing additional nitrogen to the soil systems. Similar findings are reported by Sanginga and Woomer (2009) in systems intercropped with grain legume crops such as cowpea, mungbean, soybean for improving soil health. According to Peoples and Craswell (1992) the legumes can add 80 to 350 kg N ha⁻¹ in soil. Besides, intercrops may reduce competition in the mixture for a particular nutrient affecting growth or prevent depletion of any one essential element in the soil compared to sole crop (Vandermeer 1989). This could explain the reasons for higher yield of mango with French bean/ cowpea systems. The phosphorus availability in soil depends on many factors but most importantly to the total micro flora and particularly to the phosphorus solubilizers in the rhizosphere of plants. Dahmardeh et al. (2010) found that intercropping of maize-cowpea significantly increased the phosphorus and potassium in soil compared to sole maize treatment, thereby increasing higher grain yield, in accordance with other workers (Jensen 1996, Hauggaard-Nielsen et al. 2001). Intercropping systems also promote greater yield stability than monoculture (Sahoo et al. 2015). Indirect effect of tree canopies in reducing the nutrient losses through runoff and sediments and nutrient mining from subsurface layers and their efficient cycling could have

resulted in improvement of soil fertility and overall chemical soil quality in mango based intercropping systems in the present study. Our observation on the tendency of accumulation of more organic matter and nutrients in surface layer of soil in the tree-based intercropping corroborates the earlier findings made by Chijioke (1980) who stated that the bulk of organic matter and nutrients are added in the top soil from the standing trees through litter fall, dead and falling leaves, twigs, branches etc. Similarly, our findings are in conformity with Swain et al. (2012) who have found that the intercropping systems were effective in bringing gradual improvement in the physicochemical properties of the orchard soil.

The results of the trial also indicated that mango as base crop is influenced by the intercrops in respect of its yield performance. Mango yield could be influenced by several factors such as eco-physiological conditions, variety and cropping methods and otherwise by the yield parameters such as tree density, number of panicles per tree, fruit number per panicle and fruit weight (Bhuva et al. 1988), besides, to the component intercrops and filler crops in the fruit based agroforestry systems (Vishal Nath et al. 2003). The improvement in mango production in cowpea or roselle+French bean systems are obviously related to nitrogen fixing abilities of the legume intercrops which must have supplemented the nutrient requirement of the mango crop. Similar benefits from the legume intercrops to other fruit trees have been reported; e.g., mango (Anon. 1987), coconut Sharma and Choudhary 2002) and sweet orange Ghosh et al. 1997).

The mango yield parameters in the present study were strongly influenced by the type of intercrop in the system. The number of fruits per tree was highest in plots intercropped with roselle in combination with French bean and cowpea compared to other intercrops. This may possibly be linked to better nutrient balance in these systems coupled with other favourable conditions provided by the intercrops as was evident from relatively higher yield attributes of mango in intercrops than the sole crop. Legume crops intercropped in tropical fruit tree production have been found to act as important cash and trap crops. Apart from fixing atmospheric N, recycling nutrients and improving soil nutrient availability, they also help reducing erosion risks and organic matter losses (Lehmann et al. 2000). Moreover, these cover crops may also attract insects through attractive blossoms, which in turn favour the pollination of mango.

Several factors affect the growth of a species used in intercropping such as cultivar selection, seeding

ratios, and competition between mixture components for various natural resources (Papastylianou 1990, Cabellero et al. 1995, Carr et al. 2004, Dusa and Roman 2009, Dusa and Stan 2013). In mono cropping the competition for various resources is somewhat selective and therefore on many occasions, their yield is better under sole crop than when they are grown in association with other crops in intercropping systems. In the present study intercropping reduced the yield of some crops by 10-20% yield while other crops were not affected or had better yield. The land equivalent ratio (Table 5) was highest in cowpea (3.52) followed by 3.50 in roselle+French bean intercropping. These results show that, in sole crop, 250-252% more land areas would be necessary to obtain the same yields like in these intercropped systems. All the combination of intercropping in this research have shown superior land efficiency of intercropping than the sole mango crop. As far as mango yield is concerned, the LER results show that 16% more land would be necessary in control (sole mango plot) to have the same yield as in pineapple intercropped plot to as high as 163% more land in control to have same yield as in cowpea intercropped plots.

Notwithstanding selection of appropriate intercrop is very important for obtaining higher biological efficiency and yield of crops. The shade effect on the intercrops by the base crop mango might have affected the production of light sensitive crops, as is seen from the reduced yield of many intercrops over the respective crops when grown alone (mono cropping condition). Paddy might have been affected more due to its need for light and water content of the soil. Similar effect has been reported earlier by Ghosh (2001) who suggested that paddy should be excluded from the cropping pattern under rain fed upland situation. However, growing of turmeric under mango resulted in better yield of this intercrop by an extent of 5% (Table 5). The MEY in intercropping system with paddy was almost similar with the MEY in sole mango crop which mean that paddy was not beneficial in bringing better yield in fruit crop. Higher MEY in intercropped than the base mango crops revealed extra income to the farmers. Higher LER in intercropping systems than the sole crop augmented the net return from unit area leading to better utilization of land and higher monetary return. These findings are in accordance with several others (Singh et al. 1976, Kannan and Nambiar 1976) who found intercropping to be more profitable than sole crops.

CONCLUSIONS

Mango based farming systems at East Kawlchaw village in Saiha district of Mizoram, North-East India have proved to be a better option for the farmers in generating extra income from the intercrops while attaining better yield from the main mango crop. The mango trees are capable of pumping nutrients from deeper soil layers and also scavenge leached nutrients through horizontal root expanse which cannot be tapped by agriculture crops. Thus, when the mango trees got associated with the intercrops, the system as a whole was more productive than the respective sole crops. Though all intercropped plots have beneficial effect on soil health and crop yield, the cowpea and roselle+French bean systems could be the most suitable crops while pineapple and turmeric too can be suitably practiced to enhance income and better resource conservation.

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