Content list available at http://epubs.icar.org.in, www.kiran.nic.in; ISSN: 0970-6429

Indian Journal of Hill Farming

June 2023, Volume 36, Issue 1, Page 144-152

Alternate land use systems for newly developed mango orchard in improving farm productivity and profitability under hilly upland of Odisha

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ARTICLE INFO

Article history:
Received: 18 January, 2023
Revision: 24 January, 2023
Accepted: 13 April, 2023

Key words: *Alternate land use system, land intensification, nutrient balance, intercropping, soil fertility, system productivity, farm profitability*

DOI: 10.56678/iahf-2023.36.01.18

ABSTRACT

The alternate land use (ALU) system within the fruit orchard in hilly undulating land area is a suitable rainfed technology to minimize risk of crop failure, achieve stability in farm production and suitably meet the challenges and the vagaries of weather under dryland condition. An experiment was undertaken in the research farm of All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Odisha University of Agriculture and Technology (OUAT), Phulbani during 2016-17 to 2017-18 to study the impact of different intercrops vegetables (cowpea, radish) and intra-crop papaya accommodated in intra-row spacing of mango (4 m x 4 m) due to lower row-spacing (2mx 2m) within newly developed mango orchard under different nutrient management practices on the system productivity, farm profitability and soil fertility. Three nutrient management practices such as (i) organic management, (ii) integrated nutrient management (INM) and (iii) conventional method were taken as main plot treatments whereas three horticultural crops such as cowpea, radish and papaya were taken as subplot treatments. The investigation revealed that the integration of fruit and vegetables within mango orchard under INM practice registered higher productivity and improved soil moisture than other nutrient management practices. The radish and cowpea as intercrop with fruit trees recorded higher net income (₹73, 450 ha^{-1}, ₹86,700 ha^{-1}),B:C ratio (3.41, 3.16), RWUE (rainwater use efficiency 9.45, 8.27 kg $ha^{-1}mm^{-1}$) and positive nutrient balance than intra-cropped fruit trees. All horticultural crops under INM, resulted higher value in terms of yield, crop economics and soil nutrient status. Hence, cowpea, radish as inter row crops and papaya as intra row crop can profitably and sustainably be grown in rainfed uplands of Odisha because of their ability to improve soil fertility, productivity and fulfill the monetary requirement of the farmers providing resilience to the rainfed farming.

1. Introduction

Instability and un-sustainability of yield due to mono cropping system is one of the important reason for food insecurity in rainfed areas which has lower resilience to environmental perturbations and biotic stresses for the marginal and small scale farmers (Ngwira *et al.* 2012). Rainfed farming is affected by soil and water erosion, lower productivity, lower water holding capacity, nutrient loss, and decline in edaphic characters caused by climatic change and under utilization of natural resources (Bastia *et al.* 2020). Farmers of rainfed upland in hilly districts of Odisha cultivate fruit trees without utilizing inter and intra spaces and available farm resources optimally which often results in under production and poor economic return. Lateritic soils under this rainfed area, are invariably are prone to erosion, low in organic carbon and poor in N, P and K contents with lower water holding capacity (WHC). Poor management of marginal lands, particularly the topmost soil layer of the

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undulating topography in rainfed upland results in surface land degradation for which crop production is either low or extremely uncertain and unstable. Hence, diversification of cropping systems in time and space through alternate intercropping systems especially with high value short duration vegetables and perennial fruits may improve crop yields by diagnosing and treating limiting factors for production (Radosavljevic *et al.* 2020).

For profitable cultivation, alternate land use systems within orchard is advocated for these marginal lands which would result in reduced soil-nutrient loss, increase crop productivity under the different land configurations prevalent in the dryland condition (Khokhar *et al.* 2021). Basically, horticultural crops within an orchard utilizes the vacant inter and intra spaces and improves soil health or supports primary species growth. It is the cheapest rainfed technique to boost system productivity and farm health which may bring additional income to system yield besides improving WHC, mitigates yield damage by wind and air born particles, decreases sedimentation, boosts soil fertility and participates in N-fixing (if legume crop) enriching N-content in soil. Aligning crop choices coping with weather aberrations, matching resource endowments and market demand are the key factors that help in risk minimization and enhance production, productivity and profitability of the rainfed farmers (Reddy *et al.* 2022).

The alternate land use system is a practice when a inter spaced land is put under an alternative strip cropping systems in order to match its capability more appropriately to the new land use and achieve more sustainable biological and economic productivity on a long term. It is aimed to optimize the use of resources through recycling, internalize the input production and reduce the risk and conservation of natural resources. It reduces the erosivity of rainfall and erodibility of soil through dissipation of energy of raindrops by canopy and improves the soil organic matter, physico-chemical and biological properties of soil (Gupta *et al.* 2019). The agri-horti alternate land use systems is one of the most important dryland technologies in terms of economic returns and farm productivity to the farmers and their preferences (Bastia *et al.* 2020; Radosavljevic *et al.* 2020). Fruit based agri-horti system i.e. fruit trees intercropped with agricultural crops could be an alternate land use system for these land (Saha *et al.* 2014). As both mango and papaya are perennial fruits but raw papaya can be used as vegetables in short period and can be accommodated within intra-row spacing of mango (4m x4m) as its spacing is 2m x2m, hence their intercropping can be called as intra-cropping. It was also observed that the dry land horticultural fruit trees like mango, papaya integrated with short duration arable crops like legumes, pulses and vegetables were the most profit oriented among different agri-horti systems. Further, convergence of programmes/schemes of national and state governments are needed for scaling out alternate sole crops/intercropping systems for achieving risk resilient and sustainable rainfed agriculture (Reddy *et al.* 2022). Large areas have been diverted to mango plantation under National Horticulture Mission (NHM) programme in Odisha, which remain unproductive for first three years. Under this system, fruit tree can be grown successfully with another short duration fruit crop such as raw papaya in intra space and vegetables such as radish, cowpea, greengram, blackgram as bonus crops and this system can be a profitable model for marginal and sub marginal lands (Biswas *et al.* 2003; Mynavathi *et al.* 2017). Therefore, the present investigation of alternate land use systems such as inter and intra cropping systems of papaya and vegetable, was carried out in the newly developed mango orchard through land intensification to develop a suitable agri-horti alternate land use system for rainfed areas of Odisha which may help the small and marginal farmers to improve their farm productivity, profitability and sustainability.

2. Materials and methods

The experiment was conducted at the Research farm of All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Odisha University of Agriculture and Technology (OUAT), Phulbani during 2016-17 and 2017-18. The experiment site belonging to North Eastern Ghat Zone of Odisha, is located at 20^0 28’ N latitude, $84^0$14’E longitude, 518.0 m above mean sea level (MSL) and have a tropical sub-humid climate with average annual rainfall of 1407 mm, concentrated mostly during *kharif* season. The crop geometry within the experimental site and the crop calendar are given in the Fig 1 and Table 1 respectively. The soil is sandy loam, low in organic carbon (3.15 g kg^{-1}), field capacity at 13.1% (w/w basis) at permanent wilting point at 5.5% (w/w basis), low to medium in fertility status with slightly acidic to neutral (pH - 5.4) in soil reaction. The available nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) in the soil layer of 0-15 cm were found to be 187.5, 34.2, 194.8 and 22.4 kg ha^{-1} respectively. Soil nutrient status of each plot was recorded before commencement of the experiment and after completion of the experiment.

The onset of monsoon was at right time of normal date of 10^{th} June during 2017-18 whereas it was delayed by 14 days during 2016-17 but its cessation during 2017-18 was prolonged by 12 days (21^{st} October) than that of 2016-17 (9^{st} October). The total rainfall during 2016-17 (1248.8 mm) and 2017-18 (1265.9 mm) were found to be 11.2% and 10.0% less than the normal rainfall (1407 mm) respectively. The total number of dry spells during the *kharif* seasons of 2016 and 2017 were found to be three and four of 41 days and 37 days duration respectively whereas total numbers of rainy days during the respective period were 60 days and 66 days respectively. The comparative monthly rainfall distribution pattern during 2016-17 and 2017-18 at the experimental site is given in Figure 2.

The experiment was laid out on split plot design with three replications taking three nutrient management practices such as (i) 100% Organic (FYM @ 5 t/ha, NPK (%): 0.52: 0.25: 0.45), (ii) Integrated Nutrient Management, INM (50% organic + 50% conventional), (iii) Conventional (RDF for vegetables @ 25:50:25 NPK kg ha^{-1}) in main plot and four cropping systems such as (i) sole mango (4m x 4m) (M), (ii) mango+ raw papaya (2m x 2m) (M+P), (iii) mango+ raw papaya + cowpea (30cm x 15cm) (M+P+CP) and (iv) mango+ raw papaya + radish (30cm x 10cm) (M+P+R) cropping systems in sub plot.

The cultivars taken for the experiment were hybrid mango (var. Amrapalli), cowpea (var. Gomti), radish (var. Pusa Chetki) and hybrid papaya (var. Pusa Majestic). The plant saplings of 625 ha^{-1} for mango, 1250 ha^{-1} for papaya and a seed rate of 20 kg ha^{-1} for cowpea and 12.5 kg ha^{-1} for radish respectively were used for maintaining normal plant population and standard package of practices for each crop was followed from sowing to harvesting. No agri-input cost except the saplings, planting, harvesting including fertilizer or irrigation was taken into account in the plantation crops while all intercultural operations were followed in all agricultural crops as per standard practices with occasional emasculation and lopping in mango in 2nd year to hasten early fruiting. The harvesting of papaya as vegetables was recorded from March, 2017 to May, 2018 while it was for two *kharif* seasons for two intercrop vegetables but none for mango within two experimental years.

System profitability of different alternate cropping systems under mango orchard over the years was calculated by using prevailing market price of inputs and outputs. In order to compute the profitability, the net returns and benefit-cost (B:C) ratio were calculated. The gross returns (₹ ha^{-1}) were computed as a product of mean yield of each treatment and market price of the crop. The net returns (₹ ha^{-1}) were computed as a difference of gross returns and cost of cultivation (₹ ha^{-1}) for each treatment. The B:C ratio was derived as a ratio of gross returns and cost of cultivation for each treatment (Barik *et al.* 2015). To compare the system yield among treatments, Papaya Equivalent Yield (PEY) was computed by using the formula as suggested by Behera *et al.* (2012).

$$PEY = \frac{(Yc \times Pc)}{Pp} + Yp \qquad [1]$$

Where Y_c, Y_p are yield (kg ha^{-1}) of concerned crop and papaya respectively and P_p , P_c are prices of papaya (₹ kg^{-1}) and the concerned crop (₹ kg^{-1}) respectively. The rainwater use efficiency (RWUE) for different crops was determined as the ratio of papaya equivalent yield (PEY) and the total rainfall received by the system during the growing seasons of two years (June, 2016 to May, 2018) (Ali *et al.* 2007).

$$RWUE = \frac{PEY}{Rf} \qquad [2]$$

Where, PEY is the papaya equivalent yield (kg ha^{-1}) and R_f is the effective rainfall (mm) received by the crop from sowing to harvesting. The rainfall consumed by each crop is given below in Table 2. The water holding capacity (WHC) of soil was measured on weight/weight basis before sowing and harvest of crop after two years of experiment period using the Kneer-Raczkowski box method.

$$\text{WHC (\%, w/w)} = \frac{Total\ water\ in\ saturated\ soil\ (g)}{Oven\ dry\ weight\ of\ the\ soil\ (g)} \times 100 \qquad [3]$$

The significant differences among treatments were compared with the critical difference at 5% level of probability (Gomez and Gomez 1984).

3. Results and discussion

Effect of alternate land use systems on soil properties

The soil pH, soil organic carbon (SOC), water holding capacity (WHC), available nitrogen (N), phosphorus (P) and potassium (K) in different alternate inter and intra cropping systems were measured before sowing during 2016-17 as well as after harvesting of the crops during 2017-18 and the results are presented in Table 1. Higher value for SOC, WHC, available soil N, P and K were observed in different cropping systems as compared to sole mango treatment under INM practice than other nutrient management treatments which indicated the improved soil fertility and positive nutrient balance in soil due to cropping system in INM. Effective recycling of organic residues coupled with nutrients and moisture absorption by highly branched and deep rooted plantation crops supplied by different agricultural crops in the study eventually caused this improvement. The percentage increase in soil WHC, pH, organic C, available N, P and K by different alternate cropping systems after two years of cropping is given in the Fig. 3.

The SOC and pH were increased marginally from the initial condition by all nutrient treatments from which INM was the best treatment in retaining maximum SOC (17.6%) and reducing maximum soil acidity (18 %) followed by organic (13.3%, 9.3%) and conventional (6%, 7.8%) treatments respectively after harvesting of the crops. In case of different alternate cropping systems of fruit tree with vegetables, such as (M+P)+R and (M+P)+CP in the experiment period, the SOC was increased by 10.2-11.4 % and their WHC also enhanced by 9.6-19.2%. Even in exhaustive intra cropping of M+P trees, the SOC, WHC and pH in soil also increased considerably from 3.05 g kg^{-1} to 3.27 g kg^{-1} (7.2%), 11.3 % to 12.1 % (w/w) and 4.8 to 5.1 (6.3%) respectively.

The spatial and temporal intensification of land through arable intercropping and enhanced biomass production per unit area and time by them invariably increase the organic carbon, WHC and pH status of the native soil (Barik *et al.* 2015; Khokhar *et al.* 2021). It may be explained by enhanced ecosystem and microclimatic modification like proliferation of rhizosphere, nitrogen fixation by legume vegetable of cowpea and crop residue decomposition. Furthermore, application of fertilizer to rainfed vegetables, moisture extraction and retention by deep rooted cowpea and fruit trees (mango, papaya) might have increased the organic C and WHC of soil after decomposition of crop residues (Mynavathi *et al.* 2017). The same may be the reason for enhanced soil properties of sole mango treatment as being a perennial crop, it has the ability to absorb, extract and utilize the underneath, added soil nutrients, moisture by the companion crops and nutrient management practices through the root-transfer process (similarity in root physiology with papaya) although no external agri-input was applied to it. Similarly, the available N, P and K were increased by 2.2-10.6%, 22.4-29.8% and 4.1-11.1%, respectively by main-plot treatments and 7.2-13.1%, 14.4-29.8% and 6.3-11.5%, respectively by sub-plot treatments after harvesting of the intercrops in two years from the initial condition (Fig. 3) which is supported by Bastia *et al.* (2020) and Saha *et al.* (2014).

Yield, RWUE and economics of different alternate land use systems

The intercrop of cowpea and radish (vegetables) were taken up as alternate intercropping and papaya was taken up as alternate intra-cropping with newly established mango orchards. In field condition, often it is observed that there exists a synergism between component crops of intercropping system. Some of the basic requirements of the crops are well compensated by the component crops through supplementary and complementary relationship such as root exudes, crop residues which cause differentially associated microbial activities which results in augmented farm production (Ngwira *et al.* 2012). The intercrops (papaya and vegetables) in the inter-spaces of the fruit trees of mango recorded positive effect on crop productivity and overall papaya equivalent yield (PEY) as compared to sole fruit crop. The net income and rainwater use efficiency (RWUE) from vegetables and fruits under each treatment during the study for two consecutive years are presented in Table 3.

The papaya (P) yield was found to be significantly more when it was intercropped with vegetables of cowpea (6730 kg ha^{-1}) and radish (6570 kg ha^{-1}) which were at par with each other. However, the fruit yield of papaya intra-cropped with mango (5810 kg ha^{-1}) was found to be significantly lower as compared to the above exhaustive vegetables (Table 3). Similarly, P yield under INM practice (6320 kg ha^{-1}) was found to be the best than other two nutrient treatments of organic (5540 kg ha^{-1}) and conventional (5850 kg ha^{-1}). The reason may be incompatibility and antagonistic relationship between two plantation crops in comparison to synergism between a plantation crop and a vegetable for yield differences among intercrops while INM provided the optimum soil condition for absorption of nutrient and water for both companion crops among nutrient managements. Among the two vegetables, vegetable yield of cowpea (8030 kg ha^{-1}) was more than radish (5700 kg ha^{-1}) when intercropped with M+P which may be due to legume effect of CP than non-leguminous, exhaustive R. Yield of intercrops grown under different alternate cropping systems indicated that early supplementary and/or complementary relation existed between the systems' components cause synergistic effects among the components. The results are in agreement with the finding of Saha *et al.* (2014) and Ali *et al.* (2007).

For comparison among the different agri-horti based alternate intercropping systems, the system crop yield has been converted to papaya equivalent yield (PEY). From the results of 2 years, it was found that the PEY of (M+P)+R (12,270 kg ha^{-1}) and (M+P)+CP (10745 kg ha^{-1}) intercropping systems were significantly superior than the intra-cropping of M+P (5810 kg ha^{-1}) and sole M (0 kg ha^{-1}). No significant difference in PEY was found between (M+P)+R and (M+P)+CP and both were at par with each other. However, significant difference in PEY was found among all the nutrient treatments in main plots where INM superseded other two management practices recording the maximum PEY (12,340 kg ha^{-1}) than organic (9,890 kg ha^{-1}) and conventional (10,695 kg ha^{-1}) respectively. From all the treatments in main plots, the mean equivalent yield, net return, B:C ratio were found to be 10,975 kg ha^{-1}, ₹ 78,083 ha^{-1} and 3.45 respectively whereas from all treatments in subplots, the respective parameters were 9,608 kg ha^{-1}, ₹ 62,417 ha^{-1} and 2.81. Moreover, among all nutrient managements, the RWUE of INM obtained the highest (9.51 kg ha^{-1} mm^{-1}) closely followed by conventional (8.23 kg ha^{-1} mm^{-1}) and organic (7.62 kg ha^{-1} mm^{-1}) treatment which showed that the INM practice, is more efficient than other nutrient management practices in sustaining soil moisture and enhancing farm productivity.

In the interaction effect, PEY, net income and B:C ratio of M+P was significantly less (5810 kg ha^{-1}, ₹27,100 ha^{-1}, 1.87) than its intercropping with vegetables (mean value-11508 kg ha^{-1}, ₹80,075 ha^{-1}, 8.86) while among nutrient management practices, INM was at par with conventional in tems of PEY (10695, 12340 kg ha^{-1}) and net income (₹ 74,950 ha^{-1} , ₹ 90,400 ha^{-1} but both the treatments were significantly higher than organic (10,700 kg ha^{-1},₹68,900 ha^{-1}) treatment. The lower market price of papaya (₹10 kg^{-1}) than cowpea (₹20 kg^{-1}) but higher yield and cost of cultivation are the principal reason for the above variation in economics and yield. However, among the nutrient practices, both inorganic and organic nutrients may have resulted in optimum soil condition and hence maximum PEY, net income than the other two treatments. In case of cropping system, both (M+P)+CP and(M+P)+R were at par with each other, yet significantly superior to M and M+P in terms of gross income, net income whereas INM and conventional were also followed the trend (higher income, B:C, RWUE than organic) among nutrient practices (Table 3). In this mango based orchard, the yields were only from the agricultural crops and papaya while no yield was obtained from mango. It was found from the yield analysis that the different agri-horti based intercropping systems under INM generated higher system yield, net profit and RWUE utilizing vacant spaces of the orchard as compared to conventional or organic which is well supported by Biswas *et al.* (2003) and Babu *et al.* (2016).

The results also showed that the intercropping systems of arable crops with fruit components could generate higher monetary return than intra-cropping with fruit crop alone. The (M+P)+R intercropping system registered the highest net income (₹86,700 ha^{-1}) than the other cropping systems. The net return from (M+P)+CP was found to be ₹ 73,450 ha^{-1} followed by M+P (₹27,100 ha^{-1}) and sole M (0) (Table 3). This may be due to non-complementary relationship between mango and papaya as mango did not contribute to the equivalent yield (PEY) but shared the farm resources equally with papaya. The B:C ratio of (M+P)+CP was found to be maximum (3.41) followed by (M+P)+CP (3.16), M+P (1.87) whereas RWUE was the maximum in radish (9.45 kg ha^{-1} mm^{-1}) followed by cowpea (8.27 kg ha^{-1} mm^{-1}) but M+P intra-cropping obtained the least (4.47 kg ha^{-1} mm^{-1}). This can be explained by the fact that cowpea is a deep rooted legume vegetable with highly branched rhizosphere, thus supplying soil moisture from deeper layers of soil and extracting nutrients more conveniently at critical stage thus, obtaining more yield than radish which is shallow rooted vegetable having short duration of crop period.

The B:C ratio and net return of M+P intercropping with vegetables is higher as compared to either sole cropping or intra-cropping which had also significantly higher RWUE (9.45, 8.27 kg ha^{-1} mm^{-1}) than the latter (4.47 kg ha^{-1} mm^{-1}) which may be due to mutual sharing of soil moisture at critical stages by two fruit trees and longer harvesting period. Hence, integration of arable crops with fruit trees resulted in better utilization of resources, improved fertility, higher rainwater use efficiency and provided sustainable monetary returns, thus it is an additional source of higher income and farm sustainability for dryland area. The above finding has been supported by Khokhar *et al.* (2021) in maize+ vegetables strip intercropping system under rainfed condition. holding capacity of soil. This improved soil characters were due to the efficient recycling of organic residues from different intercrops and their differential moisture extraction pattern. The integration of vegetables with plantation crops within orchards registered higher gross income than plantation crop alone. The radish among intercrop vegetables, recorded the highest net income (₹86,700 ha^{-1}) B:C ratio (3.41) and RWUE (9.45 kg ha^{-1} mm^{-1}) than the other inter crops. Similarly, INM practice with in mango orchard is the most profitably (B:C ratio-3.7), sustainable (RWUE-9.51 kg ha^{-1} mm^{-1}) and remunerative (net return-(₹90,400 ha^{-1}). Hence, the intercrop vegetables and intra-crop fruit tree can be grown under INM practice in dryland condition because of their ability to improve fertility status of soil and strengthen crop economics of the system. In addition to this, the enhanced fertility and improved water holding capacity of the orchard soil enriched by the nutrient practices and intercrops, will serve as potential reservoir of resources for the perennial fruit trees for furthering yield and monetary return in future. Under aberrant weather and poor soil conditions, this agri-horti alternate cropping systems can ensure sustainable crop production for the marginal and resource-poor farmers of Odisha. Different fruit based orchards intercropped with horticultural crops holds great potential in contributing sustainable land intensification by various intercropping systems which can overcome the twin problem of land degradation and crop-diversification which may consequently provides greater food diversity and nutritional security to small and marginal farmers.

4. Acknowledgement

The authors are thankful to the All India Coordinated Research Project for Dryland Agriculture (AICRPDA), ICAR-CRIDA, Hyderabad, India and Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha, India for providing necessary financial and technical support.

5. Conclusion

The increased values of soil organic C, available soil N, P and K along with higher rainwater use efficiencies by different alternate land use systems as compared to sole orchard crop indicated the improvement in fertility and water

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Table 1. Agronomic crop calendar

Sl. No	Agronomic operations	2016-17	2017-18
1	Summer ploughing	23th May	27th May
2	Field ploughing, harrowing, levelling	21th June	23th June
3	Planting of papaya and mango, sowing of radish, cowpea	26th June	30th June
4	Gap filling and thinning	5th July	10th July
5	1st hoeing and earthing up	20th July	25th July

6	2^{nd} hoeing and earthing up	8^{th} Aug	10^{th} Aug
7	Basal dose manure/fertilizer application (FYM and RDF, (1^{st} and 2^{nd} top dressing at 30 DAS and 45 DAS respectively)	26^{th} June	30^{th} June
9	Lopping and branching in mango	March of 2017	-
10	Harvesting of crops:		
	Papaya (multiple times at 15 days intervals)	March of 2017 to May of 2018	
	Cowpea (multiple times at 7 days intervals)	15^{th}Sept.-20^{th} October	20^{th} Sept.- 25^{th} October
	Radish(3 times at 5 days intervals)	29^{th} Aug.- 12^{th} Sept.	31^{st} Aug.- 15^{th} Sept

Table 2. Effect of strip cropping systems on soil chemical and physical properties after two years (pooled of 2016-17 and 2017-18)

Agri-horti cropping systems	Before sowing (2016-17)						After harvesting (2017-18)					
	WHC (%,w/w)	pH	SOC (g kg^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	WHC (%,w/w)	pH	SOC (g kg^{-1})	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
Nutrient management systems (N)												
Organic	10.2	5.4	3.08	214.8	31.2	196.7	12.2	5.9	3.49	223.4	38.2	204.8
conventional	10.9	5.1	2.98	204.7	28.2	187.7	11.6	5.5	3.16	209.3	36.6	208.4
INM	11.2	5.0	3.12	195.7	30.8	193.7	12.7	5.9	3.67	216.4	39.2	211.5
Mean	10.8	5.2	3.06	205.1	30.1	192.7	12.2	5.7	3.44	216.4	38.0	208.2
Alternate cropping systems (C)												
Sole M	12.5	5.2	3.16	202.7	27.5	189.2	13.7	5.4	3.35	217.3	35.7	203.8
M+P	11.3	4.8	3.05	191.3	29.8	183.6	12.1	5.1	3.27	206.5	34.1	197.2
(M+P)+CP	10.4	5.2	3.26	197.6	30.5	190.5	12.4	5.8	3.63	223.4	39.7	212.5
(M+P)+R	11.5	4.9	3.15	200.5	29.4	196.3	12.6	5.3	3.47	215.2	35.8	208.6
Mean	11.4	5.0	3.2	198.0	29.3	189.9	12.7	5.4	3.43	215.6	36.3	205.5

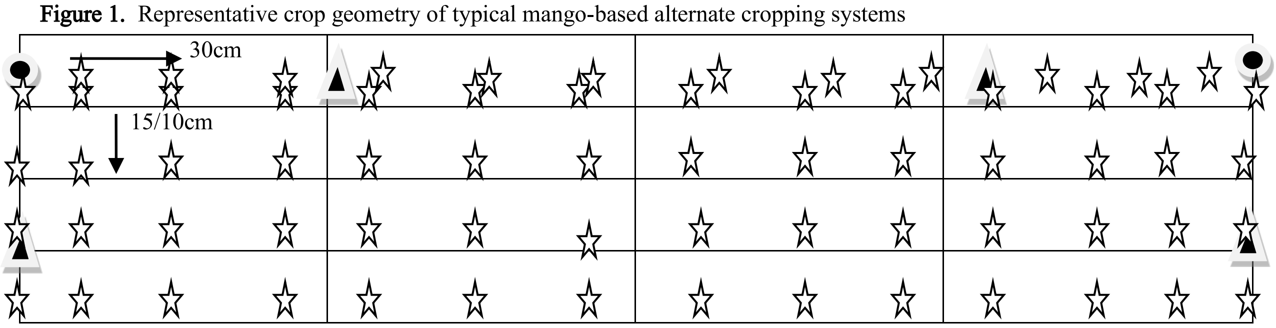
M – Mango, P – Papaya, CP – Cowpea, R- Radish

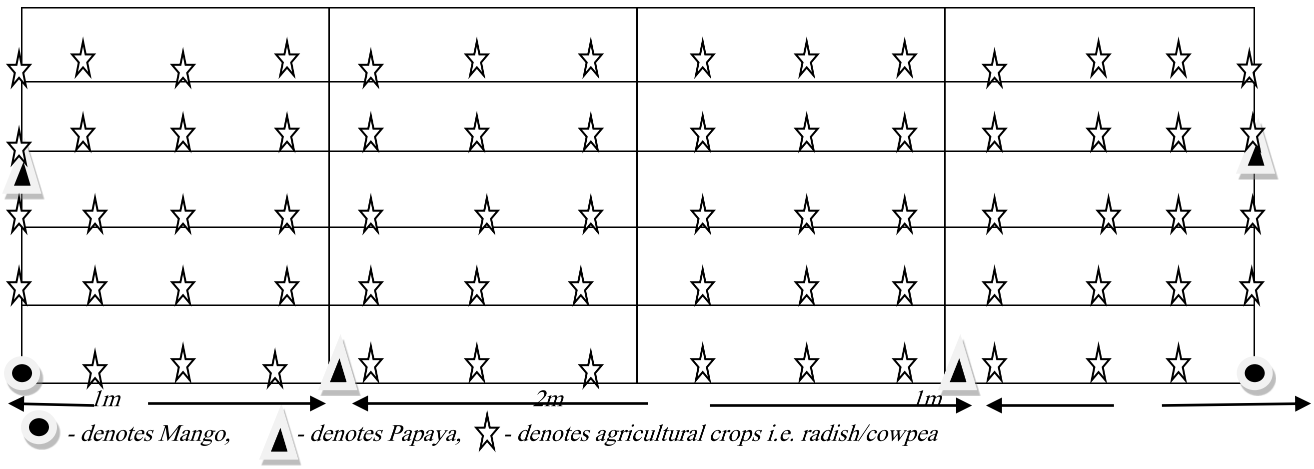
Table 3. Effect of alternate cropping systems and nutrient management practices on yield, crop economics and RWUE (pooled of two years) in newly developed mango orchard

Agri-horti cropping systems	**Crop Yield (kg ha^{-1})**	**PEY (kg ha^{-1})**	**Gross income (₹ ha^{-1})**	**Cost of cultivation (₹ ha^{-1})**	**Net income (₹ ha^{-1})**	**B:C ratio**	**RWUE (kg ha^{-1}mm^{-1})**
Main plot - Nutrient management practices (N)							
Organic	M: 0 P:5540 CP:2460 R:3120	9890	98900	30000	68900	3.29	7.62
Conventional	M: 0 P:5850 CP:2990 R:3350	10695	106950	32000	74950	3.34	8.23
INM	M: 0 P:6320 CP:3580 R:4230	12340	123400	33000	90400	3.74	9.51
Mean		10975	109750		78083	3.45	
SEm (+)		1358	6875		7490		
CD (*p=0.05*)		3786	17970		20350		
Subplot - Alternate cropping system (C)							
Sole M	M: 0	0	0	0	0	0	0
M+P	M: 0 P: 5810	5810	58100	31000	27100	1.87	4.47
(M+P)+CP	M: 0 CP:8030 P: 6730	10745	107450	34000	73450	3.16	8.27
(M+P)+R	M: 0 R: 5700 P:6570	12270	122700	36000	86700	3.41	9.45
Mean		9608	96083		62417	2.81	
SEm (+)		1218	7050		6130		
CD (*p=0.05*)		3286	19540		17165		
Interaction (N x C)							
SEm (+)		987	6120		5960		
CD (*p=0.05*)		3036	16980		17535		

PEY - Papaya equivalent yield; Market price (₹/kg): CP – 20/-, R – 10/-; P – 10/-, Mean crop seasonal rainfall (mm) during two years: CP -984.4; M & P – 1298.7, R- 929.5; (M+P)+R/CP indicates inter-cropping whereas M+P denotes intra-cropping

Figure 1. Representative crop geometry of typical mango-based alternate cropping systems





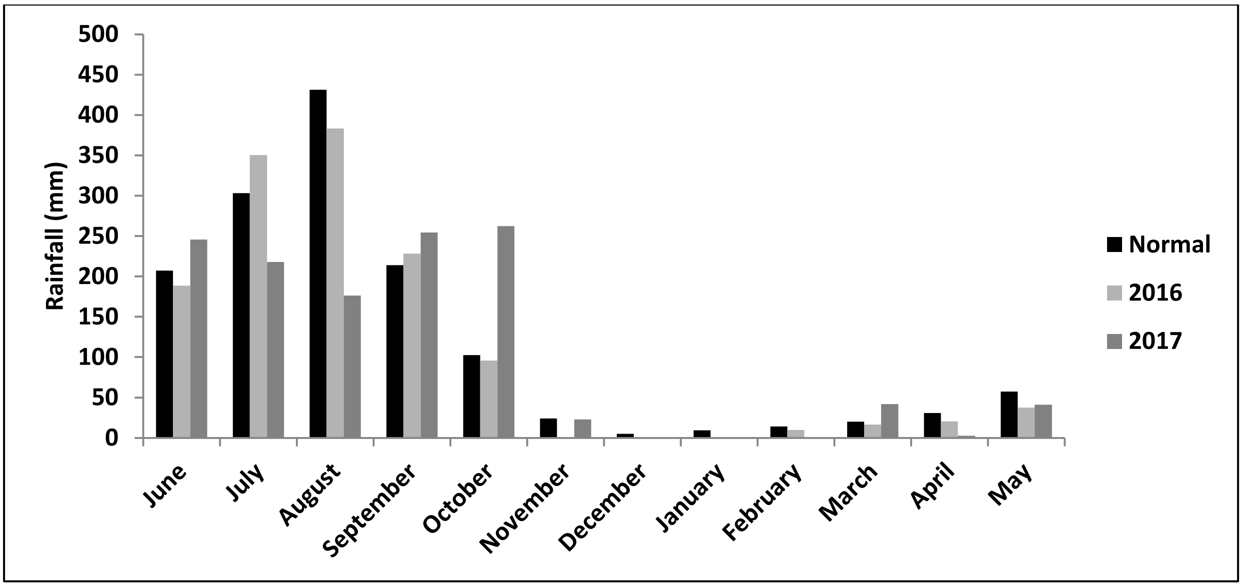


Figure 2. Comparison of month wise rainfall pattern of 2016-17 and 2017-18 with normal at experiment site during crop growing period

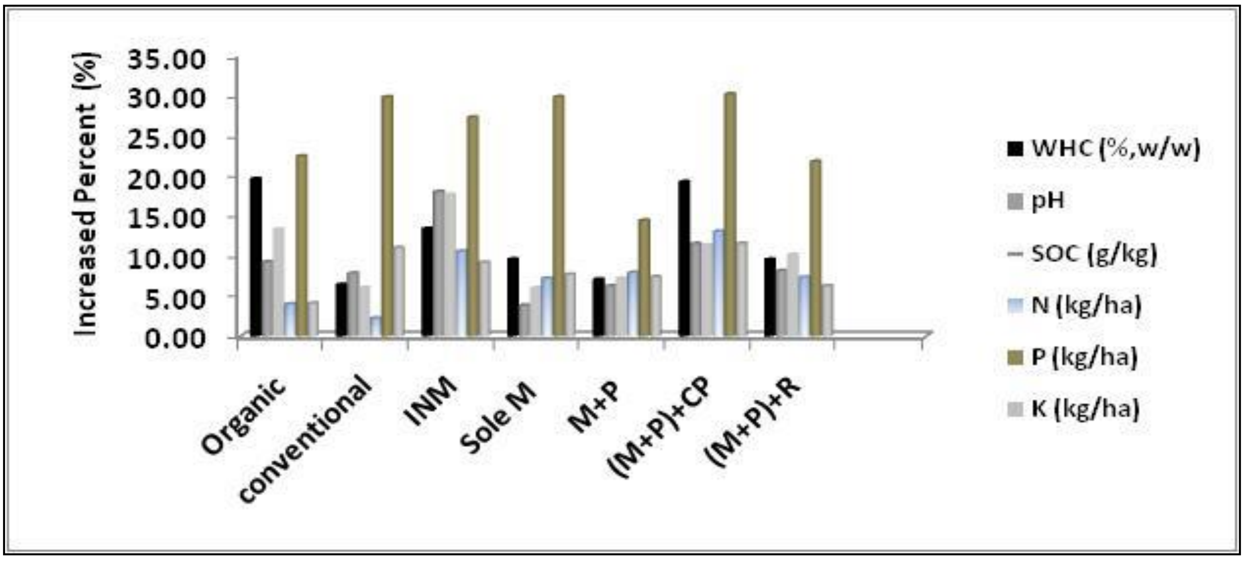


Figure 3. Increased percent (%) of different soil properties (pooled data of 2016-17 and 2017-18) by various alternate land use systems within mango orchard