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Performance of intercropping in pre-bearing mango orchards under drip irrigation in a degraded land

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Abstract
A field experiment was carried out to evaluate the performance of pre-bearing mango plantation with different intercrops (papaya, pineapple and combination of papaya and pineapple) in a sandy clay loam soil on a degraded land under drip irrigation at ICAR-Indian Institute of Water Management, Bhubaneswar, Odisha during 2017-18. Different intercrops planted in the mango (cv. Amrapali) were (i) two rows of papaya (cv. Red lady) in either side of mango plants, (ii) two paired rows of pineapple (cv. Queen) in either side of mango plants and (iii) one row of papaya and one paired row of pineapple in either side of mango plants with and without paddy straw mulch. All plants were irrigated by drip irrigation (DI) system. The amount of water used in mango–papaya cropping system (1220 mm) was higher than that in mango-pineapple cropping (975 mm). The volumetric soil water content in top 0.60 m soil in mango, papaya and pineapple were 20-23%, 21-24% and 22-24%, respectively. The vegetative growth parameters (plant height, canopy diameter and trunk girth) of young mango plants were not affected significantly either by papaya or pineapple intercropping. Straw mulch enhanced the growth parameters of mango plants by 8-12%. Similarly, growth parameters of papaya and pineapple were not affected significantly either by intercrops or by straw mulch. The highest yield (17.5 t/ha) and water productivity (21.1 kg/ha.mm) were observed in mango–pineapple system with straw much. The net profit from pineapple intercropping with straw mulch was highest (Rs. 140000/ ha) with benefit-cost ratio of 1.67, followed by papaya-pineapple intercropping with straw mulch in mango. Overall, the study reveals that mango intercropped with pineapple under drip irrigation with rice straw mulch can be practiced in pre-bearing mango orchards of Eastern India.

Keywords: Drip irrigation, Intercropping, Pre-bearing mango, Water productivity, Yield

INTRODUCTION

Long juvenile period i.e. duration between planting to fruiting is one of the major constraints in fruit production by small and medium farmers. However, due to higher profit and favourable agro-climates, the area under fruit crops has been increased from 4.01 million hectares in 2001–02 to 6.08 million hectares in 2016–17. Mango is the most important and widely grown tropical fruit crop of India, covering an area of 2.26 million hectares with an annual production of 19.68 million tonnes (GoI, 2017). Eastern India is one of the potential zones for mango cultivation with at least 3–4 years of juvenile period (Swain, 2014). The orchard growers pay substantial amount of interest on the financial investment in establishing and maintenance of orchards in the region. In this scenario, growing of suitable intercrops in mango orchards in initial periods of plantation are utmost essential.

Intercropping in mango orchards was earlier studied by different researchers. Rajput *et al.* (1989) has advocated intercrops in mango orchard during pre-bearing stage in order to get additional income. Singh *et al.* (2012) studied the effect of intercrops like cowpea, french bean, arhar, soybean, lentil, chick pea and black gram in mango and observed higher mango yield in mango-cowpea system followed by mango-lentil system and least in sole crop. Swain (2014) studied the effect of intercrops (mango ginger, turmeric, cow pea, tomato, french bean, ragi, niger, upland paddy) in eastern ghat high land zone of Odisha on mango performance and observed that the mango -guava-cowpea intercropping system exhibited better performance in relation to vegetative growth and fruit yield, closely followed by mango-guava-french bean system. Similarly, Sarkar *et al.* (2004), Ratha and Swain (2006), Raut et al. (2006), Jain *et al.* (2006), Tiwari and Baghel (2014) has also reported the beneficial or non-detrimental effect of intercrops on mango plants. Overall, it was observed that the fruit yield of mango with leguminous intercrops like cowpea, lentil, frenchbean etc. was higher than that without intercrops. The higher yield of the mango with leguminous intercrops was due to improved availability of soil nutrients probably caused by nitrogen fixation from air to soil by intercrops, reduction in soil and nutrients erosion from orchard floor due to obstruction created by intercrops, application of fertilizers for intercrops, and incorporation and decomposition of intercrop residues in soil of the orchard. In other hand, the non-leguminous intercrops benefitted the main crop through creating a better micro-climate that might help in improving fruit yield of mango.

As an evergreen tree crop, mango requires 1200–1400 mm water in a year (Carr, 2014). The higher variation of rainfall in space and time in a year creates water scarcity which causes drastic yield reduction in the crop (Panigrahi *et al.,* 2011). Moreover, the intercrops start competing with the main fruit trees for nutrients and water resulting lower orchard efficiency. Therefore, planning of inter crops in mango orchards should be based on judicious use of land, water, nutrients and solar energy available with better financial return from the orchard.

Drip irrigation (DI) has been found as a potential water saving technique in fruit cultivation (Panigrahi *et al.* 2012). However, the use of DI increases the investment in young pre-bearing orchards. The cultivation of high value fruit crops with short duration juvenile period as inter crops is one of the options to generate more profits with compensating the investment in DI in pre-bearing orchards. Very limited information is available on the performance of high value and short duration fruit crops like papaya and pineapple as inter crops in pre-bearing mango orchards under drip irrigation. Moreover, the information in a degraded land is lacking. Keeping these in view, the present experiment was undertaken to study the performance of pre-bearing mango orchard with papaya and pineapple inter-crops under DI in a degraded land of eastern India.

MATERIALS AND METHODS

The experiment was conducted in a pre-bearing mango (cv. Amrapalli) orchard in a degraded land at ICAR-Indian Institute of Water Management (20.3148° N latitude, 85.8106° E longitude and 48 m above mean sea level), Bhubaneswar, Odisha state, India during 2017-18. The intercrops taken for the study were papaya (cv. Red lady), pineapple (cv. Queen) and combination of papaya and pineapple in the mango orchard. Papaya and pineapple were planted with the spacing of 2.0 m × 2.0 m and 0.45 m × 0.60 m, respectively, in the mango plantation with 6 m x 6m spacing. The soil type of the experimental site was sandy loam with bulk density of 1.55 g cm^{-3} and pH of 6.7. The organic carbon of the soil was 0.32%. The average rainfall at the site is around 1500 mm, out of which more than 80% is confined in monsoon season (June-September) of a year.

Different intercrops planted in the mango orchard were (i) two rows of papaya in either side of mango plants with and without paddy straw mulch, (ii) two paired rows of pineapple in either side of mango plants with and without paddy straw mulch and (iii) one row of papaya and one paired row of pineapple in either side of mango plants with and without paddy straw mulch using randomized block design with three replicates. The details of treatments are presented in Table-1.

Water supply was done to each crop through DI. On-line drip irrigation (16 mm lateral pipe and 4 liters per hour emitters) was used for mango and papaya, whereas in-line drip (16 mm lateral pipe and 2.6 liters per hour emitters) was used for pineapple. The hydraulic parameters (Distribution Uniformity, Co-efficient of Variation) of the drip system, as estimated following standard procedure (Michael, 1993) were found satisfactory for irrigation. The irrigation scheduling to each crop was done on daily basis based on the crop water requirement of the crops, estimated using the procedure suggested by Doorenbos and Pruit (1984).

The recommended package and practices were followed for main crop mango and intercrops papaya and pineapple. The main crop mango was fertilized with 15 kg of FYM, 300 g N, 150 g P_2O_5 and 300 g of K_2O per plant per year. Entire dose of FYM and half dose of N, P and K should be given during monsoon (June/July) while the balance half is applied during the end of monsoon (October). The intercrop pineapple was fertilized with 12 g N, 4 g of P_2O_5 and 12 g of K_2O per plant per year. Pineapple plants were also supplied with FYM @10 t/ha. N was applied in 6 split doses. The first dose of N was given two months after planting and the last one 12 months after planting. Entire P and half of K were given at the time of planting and the remaining K, 6 months after planting. The intercrop papaya was fertilized with 20 kg FYM, 250 g N, 250 g P_2O_5 and 250 g K_2O per plant per year. The fertilizer were applied in two splits; the first in the beginning of monsoon and second in the later part. Weeding and inter-cultural operations were practiced as per the requirement.

The soil water content up to the depth of 60 cm was measured using gravimetric method. The biometric observations for mango, pineapple and papaya were recorded once in three months. The yield of papaya and pineapple were recorded by harvesting total yield from the treatments. The water productivity was estimated as yield per unit quantity of water used in total cropping sequence including mango. The total soluble solids were found out by using refractometer. The acidity of the fruit pulp samples were estimated by alkali titration method. The economics of production was worked out following the formula by Reddy and Ram (1996). The growth, yield and quality parameters recorded were statistically analyzed using analysis of variance (ANOVA) as applicable to randomized block design (Gomez and Gomez, 1984). The significance of the treatment effects was determined using F-test, and the difference between the means was estimated using least significance difference at 5% probability level.

RESULTS AND DISCUSSION

Soil water dynamics: The soil water dynamics of surface 60 cm soil depth under different crops are presented in Fig. 1. The soil water content in the profile progressively decreased from April (22.2 cm^3/cm^3) to June (21.4 cm^3/cm^3) and from December (23.7 cm^3/cm^3) to March (22.5 cm^3/cm^3). However, the soil water did not attend 50% allowable soil moisture depletion in any crop. The soil water content in root zone of pineapple plants (22 –24.1 cm^3/cm^3) was higher than that in papaya (21.9–23.9 cm^3/cm^3) and mango plants (21–23.8 cm^3/cm^3). Among the three crops, pineapple stored more soil water compared to the other crops, but they were not statistically significant.

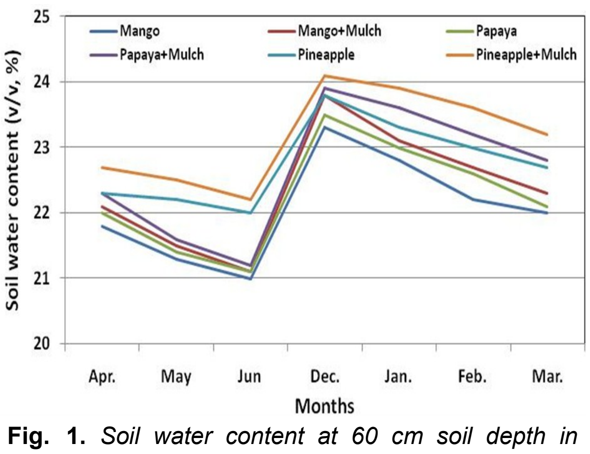

Fig. 1. *Soil water content at 60 cm soil depth in various crops.*

Vegetative growth parameters of mango, papaya and pineapple: The vegetative growth parameters of mango, papaya and pineapple are presented in Table 2. The highest plant height (3.06 m), canopy diameter (3.25 m) and trunk girth (29.3 cm) of mango was observed in mango with mulch treatment. The lowest plant height (2.50 m), canopy diameter (2.37 m) and trunk girth (26.2 cm) of mango plants was observed in mango+papaya+pineapple without mulch treatment. However, the vegetative growth parameters of mango were not affected significantly by either intercrops or mulch, as evident from non-significant values of Critical difference (CD) estimated from statistical analysis of data (Table-2). Tiwari and Baghel (2014) also didn't observe any significant effect of various mono, companion and sequential inter-croppings on main crop mango.

The highest papaya plant height (1.47 m), canopy diameter (1.44 m) and fruit set no. (12) were observed in mango+papaya with mulch treatment. The lowest papaya plant height (1.34 m), canopy diameter (1.22 m) and fruit set no. (7) was observed in mango+papaya+pineapple without mulch treatment. Similar to the growth parameters of mango, the growth parameters of papaya were not significantly affected in mango based inter-croppings. The highest shrub height (34.8 cm), number of leaves (35) and number of suckers/slips (6) of pineapple was observed in mango+pineapple with straw mulch. The lowest shrub height (31.6 cm), no. of leaves (30) and no. of suckers/slips (4) was of pineapple was observed in mango+papaya+pineapple without straw mulch. Similar to papaya, the pineapple growth parameters were not significantly affected by the mango based inter-croppings. Raut and Jain (2013) also didn't observe any significant variation in plant height and girth of filler crop (pomegranate) influenced by intercrops in mango orchard. It may be attributed to the nonexistence of competition for light, water and nutrient between the base crop mango and intercrops (Swain, 2014).

Water used, yield/Pine apple equivalent yield (PEY) and water productivity (WP) of mango based inter-cropping: The amounts of water used by the crops involved in different intercropping systems during April 2017–March 2018 are presented in Table 3. The water use of mango, papaya and pineapple were 650 mm, 570 mm and 325 mm, respectively. The mango+ papaya+ pineapple system without straw mulch had highest (1545 mm) water use followed by mango+papaya+ pineapple system with straw mulch (1360 mm) and the least in sole mango with straw mulch (572 mm). Straw mulching reduced water use by 12-15% under different mango based inter-croppings. The reduction of water use under straw mulch was due to reduction in evaporation from soil surface

Table 1. Treatment details of intercrops in mango.

Treatments	Details	Treatments	Details
T_1	Mango+ Papaya+ Pineapple	T_5	Mango+ Pineapple+ SM
T_2	Mango+ Pineapple	T_6	Mango+ papaya + SM
T_3	Mango+ papaya	T_7	Mango + SM
T_4	Mango+ Papaya+ Pineapple+SM*	T_8	Mango

*SM: Straw mulch

Table 2. Vegetative growth parameters of mango, papaya and pineapple intercropped in mango.

Treat-ments	Mango			Papaya			Pineapple		
	Plant height (m)	Canopy diameter (m)	Trunk girth (cm)	Plant height (m)	Canopy diameter (m)	Fruit set (No.)	Shrub height (cm)	No. of leaves	No. of Suckers/ slips
T_1	2.50	2.37	26.2	1.34	1.22	7	31.6	30	4
T_2	2.67	2.85	28.4	-	-	-	34.8	33	5
T_3	2.52	2.48	28.0	1.42	1.28	10	-	-	-
T_4	2.64	2.54	27.4	1.46	1.35	9	33.5	32	5
T_5	2.80	3.01	28.8	-	-	-	34.8	35	6
T_6	2.72	2.66	28.5	1.47	1.44	12	-	-	-
T_7	3.06	3.25	29.3	-	-	-	-	-	-
T_8	2.92	3.14	29.0	-	-	-	-	-	-
$CD_{0.05}$	NS*	NS	NS	NS	NS	NS	NS	NS	NS

*NS: non-significant

Table 3. Water used, yield/PEY and water productivity (WP) of mango based intercropping.

Treatments	Water used (mm)	Yield/PEY (t/ha)	WP (kg/ha/mm)
T_1	1545	11.24	7.27
T_2	975	17.14	17.58
T_3	1220	5.34	4.38
T_4	1360	11.37	8.36
T_5	828	17.48	21.11
T_6	1075	5.43	5.05
T_7	572	-	-
T_8	650	-	-
CD (0.05)	NS	1.08	0.86

PEY: Pineapple equivalent yield; WP: Water productivity; NS: non-significant

Table 4. Fruit quality of papaya and pineapple under different intercropping.

Treatments	TSS (^{o}Brix)*	Acidity (%)	Ascorbic acid (mg/100g)
T_1	9.6 (15.7)	0.16 (0.61)	50.21 (21.5)
T_2	15.3	0.66	22.3
T_3	9.4	0.18	49.96
T_4	9.8(16.03)	0.15 (0.57)	51.03 (22.0)
T_5	16.00	0.59	22.7
T_6	9.5	0.15	50.76
T_7	-	-	-
T_8	-	-	-
CD (0.05)	NS	NS	NS

* Values in parenthesis is for pineapple

Table 5. Economics of production under different inter-cropping systems with drip irrigation and straw mulch in pre-bearing mango orchard.

Treatments	Gross investment (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit-cost ratio
T_1	208000	224800	16800	1.08
T_2	208000	342800	134800	1.64
T_3	150000	106800	-43200	0.71
T_4	169000	227400	58400	1.34
T_5	209600	349600	140000	1.67
T_6	151600	108600	-43000	0.71
T_7	118000	0	-118000	---
T_8	116400	0	-116400	---

under mulch (Panigrahi *et al.,* 2010).

The yield or pineapple equivalent yield (PEY) of different mango based inter-croppings ise presented in Table 3. The mango+pineapple system with straw mulch gave significantly (P<0.05) higher PEY (17.48 t/ha) compared to other systems followed by mango+pineapple system without straw mulch (17.14 t/ha). However, the PEY of mango+pineapple system without straw mulch was statistically at par with the mango+pineapple system with straw mulch. The mango+papaya system without straw mulch gave significantly lower (5.34 t/ha) PEY. However, the PEY of mango+papaya system without straw mulch was statistically at par with the mango+papaya system with straw mulch. The mango+pineapple system registered up to 66% and 227% higher PEY compared to mango+pineapple+papaya and mango+papaya intercropping system, respectively. Earlier studies by Tiwari and Baghel (2014); Swain (2014), Swain et al., (2016) and Ghosh et al. (2017) had also reported that intercropping in widely spaced fruit crops resulted higher system equivalent yield compared to the sole crop (Tiwari and Baghel, 2014; Swain, 2014, Swain, 2016 and Ghosh et al., 2017).

The water productivity of mango based inter-croppings are presented in Table-3. The mango+pineapple system with mulch had highest (P≤0.05) water productivity (21.11 kg/ha.mm) compared to the other systems under study (4.38 –17.58 kg/ha.mm). However, straw mulching did not affect significantly water productivity of mango+papaya system. The straw mulching increased water productivity by 15-20% compared to no straw mulching in the mango based intercroppings.

Quality parameter of papaya and pineapple: The fruit quality (TSS, acidity and ascorbic acid) parameters of the intercrops papaya and pineapple are presented in Table 4. The TSS varied from 9.4 to 9.8 °Brix and 15.3 to 16.03 °Brix in papaya and pineapple, respectively. The fruit acidity varied from 0.15 to 0.18% in papaya and 0.57 to 0.66% in pineapple. Similarly, the ascorbic acid ranged between 49.96 to 51.03 mg/100g of pulp in papaya and 21.5 to 22.7 mg/100g of pulp in pineapple. However, the fruit quality of papaya and pineapple were not affected significantly in the mango based intercropping.

Economics: The economics of production under different inter-cropping systems in mango orchard is presented in Table-5. In spite of higher production cost/investment (Rs. 209600/ha), the maximum net return (Rs. 140000/ha) was generated under pineapple intercropping with straw mulch in mango orchard, due to higher return from pineapple. The benefit-cost ratio was also higher in pineapple with straw mulch (1.67) compared with other intercrops under DI in mango. However, intercropping of papaya with or without straw mulch was not found economically suitable due to less return than production cost in the crop in mango orchard.

Conclusion

The performance evaluation of pre-bearing mango orchard with different intercrops (papaya, pineapple and combination of papaya and pineapple) under drip irrigation and paddy straw mulch was studied in a sandy clay loam soil. The mango-pineapple cropping with straw mulch produced the highest yield/ pineapple equivalent yield (17.5 t/ha) and water productivity (21.1 kg/ha.mm), using least amount of water (975 mm) among the intercropping systems. Moreover, the cropping generated the highest net profit (Rs. 140000/ ha) with benefit-cost ratio of 1.67. Thus, mango intercropped with pineapple under drip irrigation and straw mulch may be demonstrated/ adopted in large scale to generate more profits in early years of mango orchards in water scarce regions of eastern India.

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