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Influence of Guava (*Psidium guajava* L.) based Intercropping Systems on Soil Health and Productivity in Alluvial Soil of West Bengal, India

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A B S T R A C T

An experiment using various guava-based intercropping systems was conducted to find out the effect of intercropping on soil health and productivity in the alluvial soil of West Bengal, India. The popular intercrops viz. eggplant, banana and pointed gourd were taken as treatments in the guava orchard along with control (a treatment without intercrop). The study revealed that the guava + banana and guava + eggplant systems were proved to be the most significant intercropping system by improving physio-chemical properties like bulk density, water holding capacity, SOC, available NPK of the soil. The maximum system equivalent yield and economic return were obtained from the same system. Thus the guava + banana intercropping system is not only the best for restoring soil fertility but also obtaining the maximum economic return for guava growers of West Bengal.

Keywords

Guava-based intercropping systems, Soil health, SOC, Fruit yield.

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Introduction

Guava is one of the most delicious tropical fruit crop all over world as well as in India (Singh *et al.*, 2016; Sau *et al.*, 2016). In India, it is grown in an area of 251 thousand hectares with the production of 4083 thousand MT (NHB, 2015). It is recognized as the third most important fruit crop of West Bengal, cultivated in an area of 14.4 thousand ha with 186 thousand MT productions (NHB, 2015), besides, mango and banana mostly in the districts of Nadia, 24 Parganas (North and South), Birbhum, Midnapore (West and East), Purulia, Bankura, Burdwan where the soils are fertile (alluvial) and having high water table. With the advancement of society, availability of cultivable land is shrinking but the food demand for the millions is increasing day by day. Today, the vertical increment in the production of fruits alone, like monocropping, neither increases income nor provides employment satisfactorily (Maji and Das, 2013). Intercropping is also considered profitable in the framework of rising demand of the households and enhanced regular employment opportunity to family labours (Ghilotia *et al.*, 2015). Adoption of proper intercropping system can provide substantial yield advantages as compared with the sole cropping without depletion of soil health (Swain *et al.,* 2012). Developing countries like India where small farms as well as labour-intensive operations are leading phenomena, intercropping plays a vital role in food-production along with yield stability over numerous crop seasons.

The fruit trees including guava are perennial in nature and take a time to come into a commercial bearing stage. During this early period of less productive stage, the farmers have very marginal income from the orchard land. So, intercropping has been employed with the main objective of greater utilization of soil resources available in the interspaces of the fruit trees for additional income by raising additional crops (Maji and Das, 2013).

Intercropping with guava is not only done for an extra profit generation but it also provides better land utilization technique through optimum production and along with maintains soil health by checking soil erosion (Bhattanagar *et al.,* 2007).

The varied soil and agro-climatic condition of West Bengal made different intercrops well suited in various fruit based cropping system. Although lot of research work has been done on guava-based intercropping systems in different parts of India but information on guava-based intercropping systems in relation to soil heath and productivity in alluvial West Bengal is insufficient. In pursuance of above findings the present investigation was therefore undertaken to evaluate the guava based intercropping systems on soil health and productivity in alluvial soil of West Bengal.

Materials and Methods

The experiment was carried out at farmer's field at Madandanga village (22°50' N latitude and 88°20' E longitudes, with an elevation of 9 m above mean sea level) of Nadia, West Bengal. The experiment was laid out in the field with homogeneous fertility and uniform textural make-up. The soil of the guava orchards of experimental site is of aluvial (Inseptisols) type, deep, moderately fertile with adequate internal drainage. The composite samples from specified depth (0–15, 15–30 and 30–45 cm) were randomly collected from five places of the experimental field with the help of screw auger prior to know the initial fertility status of the experimental field. The soil samples thus obtained were subjected to various physical and chemical analyses, and the results obtained have been presented in Table 1.

A typical sub-tropical climate prevails in the experimental site. The climate of the region has been divided into 3 seasons viz. rainy season (June to October), winter season (November to February) and summer season (March to May).

The average temperature of experimental period ranges from 20- 31 °C. May and June are the hottest months with mean maximum temperature ranging from 37 °C while the minimum, may drop down to as low as 9.4 °C during January.

During the period of experimentation the average maximum and minimum relative humidity was found to vary from 82% (March 2016) to 97.5% (July, 2016) and 39.1% (March 2016) to 86.1% (July 2016) respectively. The annual precipitation of this experimental period is 1250.8 mm in the year 2016, about 80% of which was precipitated during the four months monsoon period (June to September).

Experimental details

The experiment was carried out during 2016-17 in a 4-year-old guava orchard (cv. L 49 or

Sardar). The guava was planted with a spacing of 5m × 5m. The experimental area was divided into 20 plots of 10m × 10m and each plot consisted of 4 bearing guava trees, thus accommodated 80 trees in an area of 0.20 ha under the experiment.

The experiment was laid out as per randomized block design consisting of four treatments with five replications.

The location specific three important intercrops that mostly cultivated by farmers such as eggplant (*Solanum melongena* L. cv. *Mukatakeshi*), banana (*Musa paradisica* cv. *Grand Nain*) and pointed gourd (*Trichosanthes dioica* cv. *Kajli*) were taken as treatments in the guava orchard along with control (a treatment without intercrop).

The treatment combinations are such as T_1: Guava + Eggplant; T_2: Guava + Banana; T_3: Guava + Pointed gourd and T_4: Guava + no intercrop (Control).

Farmers maintained guava orchard of experimental area through bending technology in each year during April to get superior quality fruit in the month of October-November (somewhat offseason from normal production).

The intercrops were sown 1m away from guava tree in either side of the trunk leaving an area of 4 m^2 around each guava block. Eggplant and banana planting completed during the month of June to July whereas pointed gourd planted during the month of October.

The recommended package of practices were followed separately for the guava and intercrops. Besides natural incorporation of the foliages, the remaining biomasses of the intercrops were incorporated after harvesting of crops in the respective treatments.

Observation recorded

Post-harvest samples from the experimental field were collected from three soil depth viz. 0−15 cm, 15−30 cm and 30−45 cm. These soils were air-dried, thoroughly mixed and ground to pass through a 2-mm sieve. Different physico-chemical properties of these soil samples were determined by following the standard methods like soil texture described by Bouyoucos, 1962 and Brady and Weil, 1996; bulk density and water holding capacity as proposed by Tan, 1996; soil pH and organic carbon by Jackson, 1967.

Soil organic carbon at a depth of *i* ($SOCD_i$) was calculated as follows (Guo and Gifford, 2002):

$$SOCD_i = O_i \times D_i \times B_i$$

Where D_i is the soil depth (cm), B_i is the soil bulk density (%), and O_i is the average SOC concentration (g kg^{-1}) at a depth of *i*.

Electrical conductivity of soil suspensions (soil: water: 1:2.5) was measured at room temperature (25^0C) by using a direct reading conductivity meter (Model: Systronics, 363). Soil available N, P and K determined by following the methods of Subbiah and Asija (1956), Olsen *et al.*, (1954) and Brown and Warncke (1988), respectively.

Yield parameters

The fruit yield of guava tree was estimated by multiplying the total number of fruits per tree to the average fresh weight of fruits during harvesting and expressed as kg $tree^{-1}$ and then this value converted to t ha^{-1}, also.

System equivalent yield of each system calculated by using the following formula

$$\text{System equivalent yield} = \frac{\text{Yield of Guava} + (\text{Yield of intercrop} \times \text{Sale price of intercrop})}{\text{Sale price of guava}}$$

Economic analysis

System cost of cultivation was estimated considering maintenance cost of one ha guava orchard in its 4th year for sole guava cultivation and for other systems it is calculated by adding aforesaid cost with the cost of intercrop cultivation for respective systems. Gross return of each system calculated by adding the value of price obtained by multiplying individual crop yield to its sales price. Net return from the system was calculated by subtracting the gross return value to its cost of cultivation value of respective systems. Benefit: cost (B: C) ratio of each system calculated by dividing the net returns with cost of cultivation of respective systems.

Statistical analysis

The statistical analysis of data was done using SAS Windows Version 9.3 applying analysis of variance (PROC GLM) based on the guidelines given by Gomez and Gomez (1984) at a probability level of 0.05.

Results and Discussion

Physico-chemical properties of soil

The bulk density (BD) of guava based intercropping system during the end of the experiment is presented in Table 2. The study revealed that the guava + banana (T_2) and guava + eggplant (T_1) systems resulted in significant improvement in the bulk density of soil to 1.28 g cm^{-3} and 1.30 g cm^{-3} within 0–15 cm, 1.30 g cm^{-3} and 1.35 g cm^{-3} within 15–30 cm and 1.34 g cm^{-3} and 1.36 g cm^{-3} within 30–45 cm of soil depth as against 1.35 g cm^{-3}, 1.37 g cm^{-3} and 1.40 g cm^{-3} under control plot i.e., T_4 (guava + no intercrop). Addition of organic biomass by adoption of intercrops resulted in better aggregation properties of the soil which ultimately helps to increase soil bulk density. This was due to natural inclusion of leaves/organic residue of intercrops to the space between guava rows. Swain (2016) and Swain *et al.,* (2012) also reported decrease in bulk density of soil while studying the effect of different intercropping in guava and mango based intercropping system respectively.

The electrical conductivity of orchard soil as presented in Table 2 was increased under guava + banana (T_2) systems throughout the soil layer (0-45 cm) as compared to control plot i.e., T_4 (guava + no intercrop). The increase in the soil organic matter content may create a favourable impact in the soil physical, chemical and biological environment which ultimately resulted higher electrical conductivity in intercropped plots. The increment of soil electrical conductivity under fruit based intercropping system was reported by Swain (2016) and Manna and Singh (2001).

The guava based intercropping systems significantly changed soil pH at different soil depths. The soil pH recorded within 0–15 cm, 15–30 cm and 30–45 cm depths was found to improve by adoption of different intercropping systems (Table 2). Among various intercropping systems, the guava + banana (T_2) and guava + eggplant (T_1) system were most effective with increase in soil pH as compared to control plots i.e., T_4 (guava + no intercrop). Since, soil depth upto 30 cm is most effective feeding zone of the component crops under guava based intercropping system and maximum concentration of feeder roots in guava was found in same soil layer (Purseglove, 1974) thus change of soil pH upto 30 cm of soil depth was more predominant than that of deeper soil layer (30–45 cm). This is an interesting development in soil reaction since soil pH was increased towards neutrality which is considered as one of the most important soil health index. This was due to check in the nitrification process in the soil and addition of biomass of intercrops might have influenced the ionic exchange capacity of the soil, thus, resulting in a slow increase in the soil pH towards the intermediate favourable range. Swain *et al.,* (2016) found similar results by adopting guava + cowpea based intercropping system in Odisha.

The water holding capacity of soil influences the availability of nutrients to the plants and promotes the root activities. Soil having higher water holding capacity is always preferable for intensive cultivation practices. The studies in this regard at three soil depths carried out after end of the investigation indicated that the water holding capacity of soil was increased by the practice of intercropping systems. However, with the increasing depth of soil (0 to 45 cm) water holding capacity of soil gradually decreases (Table 2). Among different treatments, guava + banana (T_2) and guava + eggplant (T_1) based intercropping system increased the water holding capacity of soil to as compared to control i.e., T_4 (guava system without intercropping) within 0–15, 15–30 and 30-45 cm soil depths. A strong positive correlation (R^2 = 0.736) was found between soil organic carbon and water holding capacity (0−45 cm of depth) (Fig. 1) clearly suggest that increase in soil organic biomass by adoption of intercropping system not only improve soil structure, soil aeration as well as chemical and biological environment of soil but also water holding capacity. This is in accordance with the works of Aulakh *et al.,* (2004) and Swain (2016).

Fertility status of guava orchard soil

A perusal of the results (Table 3) indicates that the maximum improvement in the soil organic Carbon (SOC) content throughout the soil depths (0–15, 15-30 and 30-45 cm) was recorded to be as 0.59%, 0.55%, and 0.46% respectively under guava + banana (T_2) intercropping system, which was statistically superior than rest other intercropping system.

Soil organic carbon density (SOCD) at different soil layers also significantly improved with adoption of different guava based intercropping system as compared to control i.e., T_4 (guava system without intercropping) (Fig. 2). The maximum improvement of SOCD was recorded under guava + banana (T_2) intercropping system. The improvement of SOCD was more pre-prominent at upper soil layer (0-30 cm) than sub soil layer (30-45 cm).

The increase in higher SOC of soil under the above intercropping systems might be due to the decomposition of bio-mass and comparatively less undisturbed top soil which results to less oxidation of SOC as compared to sole guava (T_4).

Being a wide spaced fruit crop, most of soil left vacant under sole guava system resulting higher loss of soil organic matter by oxidation and less addition of soil biomass. Similar findings on increase in organic carbon content of orchard soil due to intercropping practices in fruit orchard have been reported by Vishal *et al.,* (2003), Aulakh *et al.,* (2004) and Swain (2016).

Different intercropping systems tried, the guava + banana (T_2) intercropping system significantly increased the maximum available nitrogen content of soil to 226.53, 212.03 and 181.91 kg/ha^{-1} within 0–15, 15-30 and 30-45 cm, respectively.

The effect of guava + banana intercropping system increased the available nitrogen content of soil might be due to greater recycling of bio-litters in the inter space with higher percentage of nitrogen as compared to other treatments (Das *et al.,* 2011).

Table.1 Physico-chemical properties of initial soil

Parameter	**Result**		
	0-15 cm	**15-30 cm**	**30-45cm**
Mechanical composition			
a) Sand (%)	28.4	27.4	26.9
b) Silt (%)	44.4	44.7	45.0
c) Clay (%)	27.2	27.9	28.1
Chemical composition			
a) pH	6.43	5.88	5.93
b) EC (dS m^{-1})	0.23	0.24	0.27
c) Organic carbon (%)	0.41	0.36	0.30
d) Available N (kg ha^{-1})	165.8	150.3	117.4
e) Available P (kg ha^{-1})	21.5	20.3	19.4
f) Available K (kg ha^{-1})	165.5	143.6	109.4

Table.2 Influence of guava based intercropping systems on soil physic-chemical properties

Treatment	Bulk density (g cm^{-3})			EC (dS m^{-1})			pH			Water holding capacity (%)		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
T_1	1.30d	1.35b	1.36b	0.26b	0.27b	0.29b	7.12a	6.46ab	6.17b	33.37a	32.26a	31.26a
T_2	1.28d	1.30d	1.34d	0.29a	0.29a	0.32a	7.27a	6.86a	6.50a	33.53a	32.63a	31.70a
T_3	1.32b	1.34b	1.36b	0.24c	0.25b	0.27b	7.05a	6.04b	6.10b	31.93b	30.43b	29.50b
T_4	1.35a	1.37a	1.40a	0.22d	0.23c	0.28b	6.57b	5.79b	5.99b	29.03d	29.80c	28.50c

Values (means of five replicates) in a column with the same letter are not significantly different ($P \leq 0.05$) by Duncan's multiple range test (DMRT).

Table.3 Effect of intercropping systems on nutrient status of guava orchard at the end of experiment

Treatment	SOC			Available N (kg ha^{-1})			Available P (kg ha^{-1})			Available K (kg ha^{-1})		
	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm	0-15 cm	15-30 cm	30-45 cm
T_1	0.56ab	0.51b	0.41a	205.07b	190.60b	174.10b	26.63b	24.73b	23.90ab	179.19b	164.05a	126.48a
T_2	0.59a	0.55a	0.46a	226.53a	212.03a	181.91a	29.40a	27.23a	25.20a	192.88a	175.12a	131.19a
T_3	0.53b	0.46c	0.40a	196.43b	182.17b	165.37c	24.37c	23.83c	22.43b	177.93b	140.83b	110.32b
T_4	0.42c	0.37d	0.30b	173.87d	152.83c	120.17d	22.5d	22.33d	19.83c	172.15b	128.72b	105.24b

Values (means of five replicates) in a column with the same letter are not significantly different ($P \leq 0.05$) by Duncan's multiple range test (DMRT).

Table.4 Component yield and system equivalent yield in different guava intercropping systems

Treatment	Yield (t ha^{-1})		System equivalent yield in terms of guava (t ha^{-1})	System cost of cultivation ($\times 10^3$ Rs. ha^{-1})	Gross return$^{\$}$ ($\times 10^3$ Rs. ha^{-1})	Net return ($\times 10^3$ Rs. / ha^{-1})	Benefit : Cost ratio
	Component: Guava	Component: Intercrops					
T_1	5.00 a	30.00	13.33	75.48	240.00	163.53	2.16
T_2	4.80 b	40.00	20.35	97.18	366.40	269.23	2.77
T_3	5.05 a	12.00	15.10	81.09	270.90	189.82	2.34
T_4	5.10 a	-	5.00	30.60	91.80	61.20	2.00

Values (means of five replicates) in a column with the same letter are not significantly different ($P \leq 0.05$) by Duncan's multiple range test (DMRT).

Fig.1 Relationship between organic carbon and water holding capacity of soil (0−45 cm of soil depth)

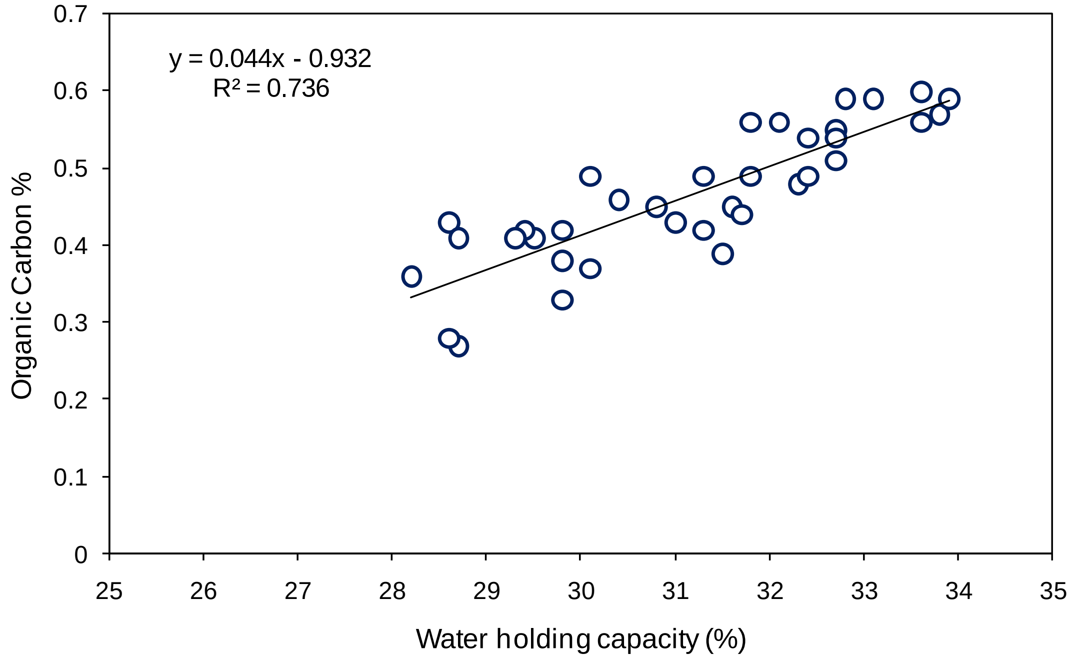
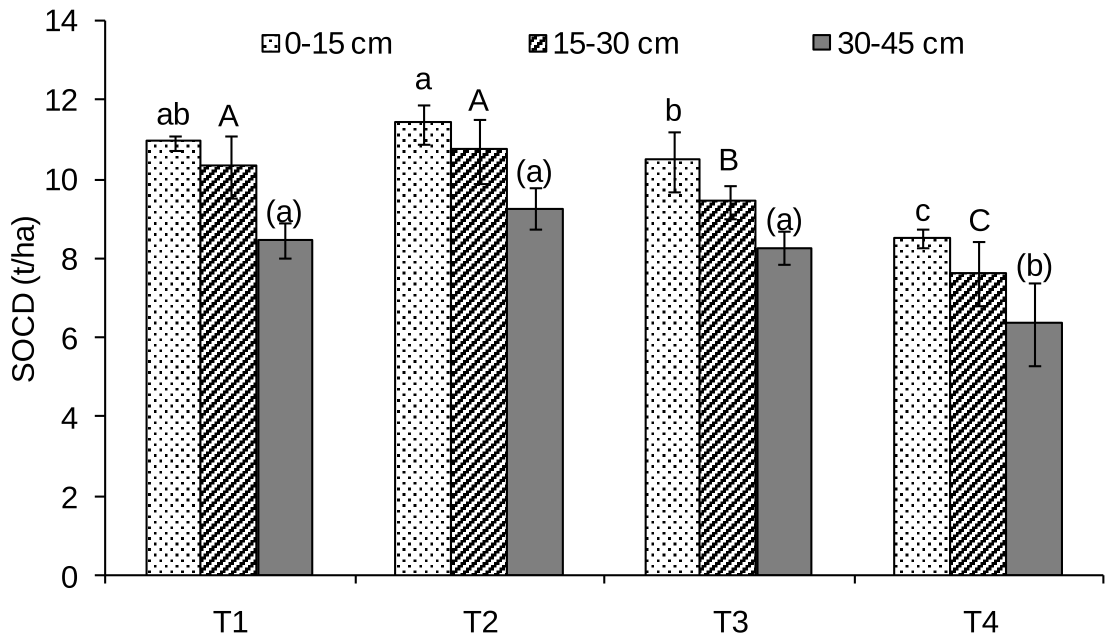
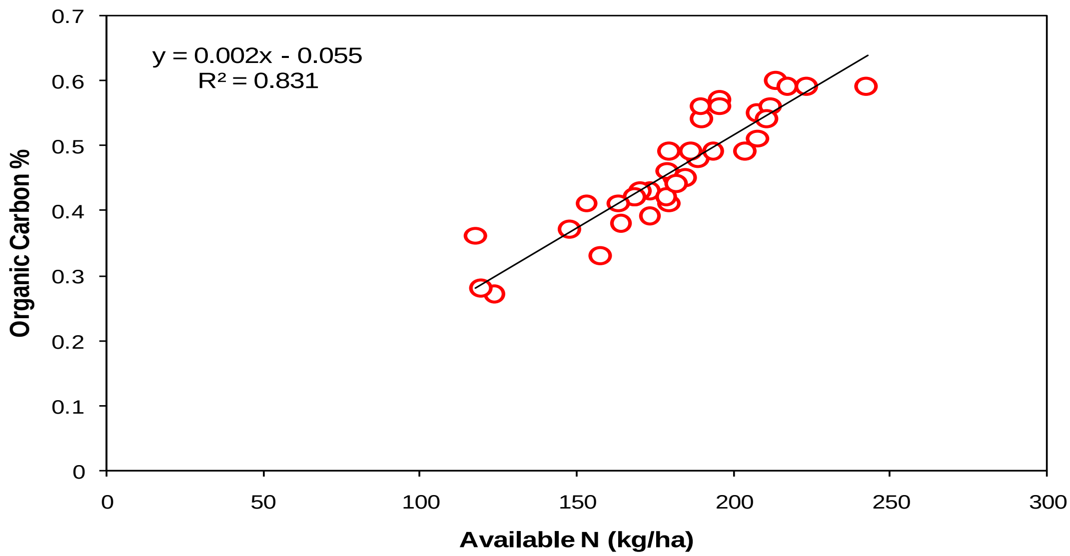


Fig.2 SOCD of different intercropping system at different soil layer (T1, Guava + Eggplant; T2, Guava + Banana; T3, Guava + Pointed gourd; T4, Guava + no intercrop)



Vertical columns (mean of five replicates) followed by error bars are the ± standard deviation of treatments. Same letter are not significantly different ($P \leq 0.05$) by Duncan's multiple range test (DMRT).

Fig.3 Relationship between organic carbon and available N of soil (0−45 cm of soil depth)



A strong positive correlation ($R^2 = 0.831$) was found between soil organic carbon and available N (0−45 cm of depth) (Fig. 3) suggested that increase in SOC by adoption of intercropping system has significant impact on improving available N status of soil. Similar results of increased available nitrogen content of the soil through intercropping in mango orchard have been reported by Swain (2016).

The study revealed that intercropping had significant effect in increasing the available phosphorus content of the orchard soil (Table 3). The available phosphorus content of soil under the guava + banana (T_2) intercropping system was increased within 0–45 cm soil depth, respectively. The increase in the availability of phosphorus content in the soil by intercropping might be due to increase in the total micro-flora population, particularly phosphorus solublizers in the rhizosphere of plant, which is in line with the findings of Verghese *et al.*, (1978). More or less, similar findings on beneficial effect of intercropping in increasing phosphorus availability in the soil have been reported by Swain and Patro (2007).

Data presented in Table 3 revealed that guava based intercropping systems proved to be advantageous in increasing the available potassium contents of soil. The guava + banana (T_2) intercropping system proved advantageous in increasing the available potassium contents of soil throughout the soil layer (upto 45 cm of depth). This corroborates with the findings of Swain and Patro (2007). The increase in availability of potassium contents in the soil might be due to increase in SOC content of soil after decomposition of biomass of intercrops that builds up total population of beneficial microbes in the orchard soil. The increment in soil microbial population may be helped to release more amount of soil K from organically fixed potassium. Similar results of improvement in nutrient status of soil due to intercropping have been reported by Gupta and Sharma (2009).

Fruit yield and economic benefit

Yield of main crop (guava) and corresponding intercrops were significantly influenced by adoption of different intercropping system (Table 3). Though sole guava system recorded the highest guava production (5.10 t ha^{-1}) but the maximum system equivalent yield (20.35 t ha^{-1}) was obtained from the guava + banana (T_2) intercropping system. Same treatment also recorded the highest gross return, net return as well as benefit cost ratio as compared to rest other treatments (Table 4). Adoption of different inter-crops in addition to main crops recorded considerable yield advantages than sole crop. The intercrops not only helped to increase the economic production but also help to develop favourable micro-climate that may have resulted in improvement of soil fertility status. The intercropping that helped to improve the system productivity was also reported by Swain (2016) in guava and Swain *et al.*, (2012) in mango.

It is concluded that the guava based intercropping systems not only recorded additional return but also increased soil physico-chemical properties gradually. Among different intercropping systems, the guava + banana system proved to be superior by recording maximum improvement of soil physical properties, SOC and available N, P, K content. The aforesaid system also recorded maximum system equivalent yield and net return.

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