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Response of Annual Legume Crops in the Allies of Perennial Fruit Trees under Coastal Upland Situation

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ABSTRACT

The coastal Odisha is vulnerable to ill effect of climate change as well as its inherent low fertility acidic upland soil gives limited crop yield. Agroforestry system with perennial fruit tree based annual legume crops might have good option for enhancement of soil physico-chemical properties and organic carbon, increase crop productivity and sustain the farmers' income in long run. The fruit based agroforestry system in coastal uplands situation has great scope of adaptability due to its, productive, ecological and economic benefits. A field study was conducted during 2020-2021 at the Agroforestry Research Station under the All India Co-ordinated Research Project on Agroforestry, OUAT Bhubaneswar in Randomized Block Design with 16 treatment combinations including 12 fruit based intercropping systems were comprised of three fruit species i.e., mango (*Mangifera indica* L.), jackfruit (*Artocarpous heterophyllus* L.) and cashewnut (*Anacardium occidentale* L.) and four pulse crops i.e. arhar, cluster bean, blackgram and cowpea and its four sole crops. Among the annual legume intercrops higher soil moisture content was observed with cluster bean irrespective of fruit tree associated. The maximum available nitrogen was observed in mango + blackgram (250.2 kg ha^{-1}). However the maximum available phosphorus content was observed in under mango + clusterbean system (64.3 kg ha^{-1}) and the maximum available potassium content was observed in under mango + cowpea system (167.1 kg ha^{-1}). The soil organic carbon of all the intercropping systems was found higher than their initial values. The maximum organic carbon change was observed in Mango+ Blackgram (T_4) (1.7 g kg^{-1}). The highest carbon sequestration in Mango+ Blackgram (T_4) (4.68 Mg C/ha-year). Out of jackfruit based intercrops the maximum tree height was recorded in jackfruit + cowpea (8.09 m), the maximum collar girth was recorded with cashewnut (73 cm) in cashewnut + blackgram, however maximum crown spread observed with cashewnut (7.69 m) in cashewnut + blackgram system at 66 months. The cashewnut + Arhar (T_9) contributed significantly maximum gross return (Rs 80,620 ha^{-1}), net return (Rs 58,620 ha^{-1}) and BCR (3.60). All the combination of fruit trees and annual legume crops were more profitable as compared to their sole cropping.

Keywords Annual legume crops, Fruit crops, Soil moisture, Soil fertility, Carbon sequestration.

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INTRODUCTION

Agricultural production in red acidic uplands soil in Odisha under rainfed condition is unstable and unproductive due to its low soil fertility, low pH and high erosion problems. These uplands are not able to sustain arable crops, particularly during the drought years. Poor management of high lands results in severe land degradation. (Guhathakurta *et al.* 2018). In order to develop some alternate land-use systems of these lands for the enrichment of soil fertility and enhance productivity fruit trees with annul legume may be the best choice. Fruit tree inter-cropped with legume being an alternative land-use system, which integrates the cultivation of arable crops and fruit trees component. Tree component increases production and income besides that, it gives stability to the farming system. It has the inbuilt capacity to increase productivity and at the same time maintain the nutrient balance as well as do carbon sequestration and environmental security. Legume component increases the productivity of soil and gives year-round income, besides imparting stability to the farming system. High-value horticultural crop also increasing productivity of the upland areas to bring prosperity. The agroforestry system has been increased attention as an approach to sequester Carbon from both developed and developing countries. It has been found that agricultural and forestry system can somewhat mitigate increasing Carbon-dioxide concentration through sequestering carbon (C). Keeping this all facts in view, a study was conducted to analyze the performance of legume intercrops, their nutrient enrichment and carbon sequestration status under a fruit-based agroforestry system for rainfed uplands agro-ecological situations of coastal Odisha.

MATERIALS AND METHODS

The research site is situation in the Agroforestry Research Station of OUAT, Bhubaneswar that is located at 20˚15' North longitude and 85˚52' East latitude with an altitude of 25.9 meter ASL level. The area has a tropical hot and humid climate, with rainfall of 1472 mm, average maximum temperature of 32.7˚C and minimum temperature of 25.2˚C. The texture of the soil is sandy loam. Iron and aluminium oxides abound, but basic captions and soluble salts are low. Before starting the experiment, soil samples were taken from a depth of 0-15 cm, using all of the recommended soil sampling protocols. This research was started in 2015 *kharif* season under AICRP project and this is the sixth year of Agri-horticultural system. Previous year also legume intercrop was grown in this site. "The experiment was laid out in a Randomized Block Design (RBD) with three replications. The experiment was consisted of 16 treatment combinations involving three fruit crops along with four legume intercrops. Three fruit tree species such as *Magnifera indica* L. (Mango), *Anacardium occidentale* L. (Cashewnut), *Artocarpous heterophyllus* L. (Jackfruit) and four intercrops are *Cajanus cajan* L. (Arhar), *Cyamopsis tetragonoloba* (Cluster bean), *Vigna mungo* L. (Blackgram), *Vigna unguiculata* L. (Cowpea) were grown in kharif season of 2020 and 2021. Before sowing the intercrops, each plot was ploughed and levelled properly after breaking up the clods and clearing the weeds. Four intercrops i.e., Arhar, Cowpea, Cluster bean, Black gram raise during the *kharif* season with a recommended spacing and package of practices.The fruit trees such as jack fruit, mango, and cashewnut were raised in 2015 by transplanting of seedlings at spacing of 8 m × 7.5 m with recommended package of practices. During the crop growth season, need based insecticides and fungicides were applied to fruit and legume intercrops. The tree heights of mango, jackfruit, and cashewnut were measured by the Nickon Hypsometer from convenient distance vertically from ground level to the tip of the leading crown. On using a measuring tape and calliper, the collar girth of individual trees was measured at 15 cm above the soil surface. The Crown spread was recorded at 12 pm noon by using shadow of crown. Crown width taken in east - west direction as well as north – south direction for taking mean of both direction. The soil samples from each treatment were collected from 0 to 15 cm depth before sowing and after harvest of each season crop for analysis of soil fertility status. The parameters such as soil organic carbon (SOC), bulk density (BD) and available N, P and K were estimated by following standard chemical analysis methods. Soil carbon sequestration was estimated by using the following formula (Singh *et al*. 2008).

C sequestration of soil (Mg C/ha/yr) = BD (Mg/m^3) × soil depth (m) × SOC % × 100

Then soil moisture content (%) calculated by gravimetric method with the following formula :

$$\text{Soil moisture content (\%)} = \frac{\text{Fresh weight – dry weight}}{\text{Dry weight}} \times 100$$

The yield of fruit tree and legumes intercrop were recorded time to time from each plot, and at the end of each season, the total yield was calculated and converted to yield per hectare. An economic analysis was conducted in order to compare the profitability of various treatments. The benefit cost ratio was computed by dividing the gross return by the cost of cultivation. The experimental data obtained were subjected to statistical analysis adopting Fisher's method of analysis of variance as out lined by (Gomez and Gomez 1976).

RESULTS AND DISCUSSION

Soil moisture content: It was observed that among the intercrops higher soil moisture content was present in cluster bean followed by blackgram, arhar and cowpea irrespective of fruit tree associated (Table 1.) It was also observed that soil moisture content decreased from September to November and then reduces gradually from December onwards, with the lowest soil moisture content observed in December in all sole crop and intercropping systems. It also observed that during the whole crop growth period, more moisture was found in lower depths relative to the surface soil layer in all systems. From September to November, sole legume crops grown in open circumstances had greater available soil moisture content, but after December, higher available soil moisture content was observed in all intercropping systems compared to open control (T_{13} to T_{16}) conditions regardless of the fruit trees."When the soil moisture was low towards the end of the *kharif* season, (Table 1) there was lower evaporation loss under the tree canopy, Avinash *et al.* (2013) observed that mango intercrop plantation had highest soil moisture content as compared to sole mango plantation.

Available nitrogen: It was found that the available nitrogen content from fruit based agroforestry systems were higher as compared to the initial status (213.8 kg per hectare). The maximum available nitrogen was observed in Mango + Blackgram (T_4) (250.2 kg ha^{-1}) then after Mango + Cowpea (T_3) (243 kg per hectare) and the lowest available nitrogen content

Table 1. Soil moisture content (%) in fruit-based agroforestry system and sole legume crop (Pool data of 2020-2021).

Treatments	September		October		November		December		Mean	Mean
	15-30 (cm)	30-60 (cm)	15-30 (cm)	30-60 (cm)	15-30 (cm)	30-60 (cm)	15-30 (cm)	30-60 (cm)	15-30 (cm)	30-60 (cm)
Mango+ Arhar :T_1	12.4	13.5	11.4	12.7	11.51	13.43	7.14	9.7	10.61	12.33
Mango+ Cluster bean :T_2	11.44	13.82	10.87	13.98	11.67	13.42	10.31	12.84	11.07	13.51
Mango+ Cowpea :T_3	13.07	14.2	12.15	13.28	9.68	11.19	7.28	9.56	10.54	12.05
Mango+ Blackgram : T_4	11.57	13.65	11.35	13.46	10.88	12.66	8.17	8.64	10.49	12.10
Mean	12.12	13.79	11.44	13.35	10.93	12.67	8.22	10.18		
Jackfruit + Arhar :T_5	11.24	14.49	10.41	11.47	9.37	11.34	9.11	10.63	10.03	11.98
Jackfruit + Cluster bean :T6	12.4	13.61	11.45	12.33	10.96	11.46	8.19	10.77	10.75	12.04
Jackfruit + Cowpea :T_7	12.45	13.63	11.26	12.26	10.62	11.89	8.56	10.44	10.72	12.05
Jackfruit + Blackgram :T_8	12.68	13.53	11.42	13.43	10.45	12.62	9.82	10.84	11.09	12.60
Mean	12.19	13.81	11.13	12.37	10.35	11.82	8.92	10.67		
Cashewnut + Arhar :T_9	12.78	13.42	11.78	12.62	10.62	12.57	8.87	10.61	11.01	12.31
Cashewnut + Cluster bean :T_{10}	12.37	13.78	11.69	12.56	11.27	12.22	8.53	10.44	10.96	12.25
Cashewnut + Cowpea :T_{11}	11.84	13.85	10.71	12.81	9.36	11.46	7.28	7.82	9.79	11.48
Cashewnut + Blackgram :T_{12}	11.58	12.78	11.74	12.15	10.84	12.03	7.73	10.07	10.47	11.75
Mean	12.14	13.45	11.48	12.53	10.52	12.07	8.10	9.73		
Sole Arhar : T_{13}	12.49	13.27	11.22	12.31	10.69	12.93	8.65	10.42	10.76	12.23
Sole Cluster bean : T_{14}	12.71	13.75	11.67	12.79	10.81	12.37	8.41	10.87	10.9	12.44
Sole Cowpea : T_{15}	12.83	11.46	11.71	12.56	10.58	12.32	7.43	9.53	10.63	11.46
Sole Blackgram : T_{16}	12.94	13.92	11.49	12.75	10.53	12.64	8.32	10.59	10.82	12.47
CD (0.05)	0.06	0.28	0.21	0.05	0.07	0.13	0.42	0.36	0.02	0.08

Table 2. Available N, P, K in soil under fruit based agroforestry system (Pool data of 2020-2021).

Treatments	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Initial soil status (2015)	213.8	44.8	144.1
Mango+ Arhar :T_1	231.8	55.6	149.4
Mango+ Cluster bean :T_2	238.9	64.3	155.6
Mango+ Cowpea : T_3	243.0	54.4	167.1
Mango+ Blackgram :T_4	250.2	50.7	158.5
Jackfruit + Arhar :T_5	216.6	53.1	147.2
Jackfruit + Cluster bean :T_6	218.3	57.6	153.5
Jackfruit + Cowpea :T_7	216.8	50.1	164.1
Jackfruit + Blackgram :T_8	234.2	48.1	157.1
Cashewnut + Arhar :T9	214.7	49.1	146.2
Cashewnut + Cluster bean :T_{10}	216.1	53.2	150.2
Cashewnut + Cowpea :T_{11}	220.2	48.4	157.4
Cashewnut + Blackgram :T_{12}	229.1	47.4	153.1
CD (0.05)	4.1	2.1	3.8

was found in Cashewnut + Arhar system (T_9) (214.7 kg per hectare). The available nitrogen trends in different intercropping systems were: T_4> T_3> T_2> T_8> T_1> T_{12}> T_{11}> T_6> T_7> T_5> T_{10}> T_9. It data also says blackgram based intercrop contribute most and arhar based intercrop contribute lest nitrogen in soil (Table 2). The value of available nitrogen ranged from 214.7 kg ha^{-1} to 201.2 kg ha^{-1}. The maximum available nitrogen was observed in Mango + Blackgram (T_4) (250.2 kg ha^{-1}) then after Mango + Cowpea (T_3) (243 kg per hectare) and the lowest available nitrogen content was found in Cashewnut + Arhar system (T_9) (214.7 kg per hectare). The increase in available nitrogen owing to the addition of manures and fertilizer to leguminous as well as nitrogen fixation by legume intercrops such as blackgram, cowpea, and arhar over the years. (Prasad *et al.* 2014) observed that blackgram have higher nitrogen content (0.85 %) as compared to other legumes which contribute in increasing the nitrogen content in soil. Maximum nitrogen concentration in intercropping treatment of cowpea was observed by. (Bedse *et al.* 2015).

Available phosphorus: "The available phosphorus content of fruit-based agroforestry systems was found higher compared to the original state (44.8 kg ha^{-1}).The maximum available phosphorus content was observed in under Mango + Clusterbean system (T_2) (64.3 kg per hectare) followed by Jackfruit + Clusterbean system (T_6) (57.6 kg per hectare) and the minimum available phosphorous content was recorded in Cashewnut + Blackgram system (T12) (47.4 kg per hectare) (Table 2). The available nitrogen trends in different intercropping systems were: T_2> T_6>T_1> T_3> T_{10}> T_5> T_4> T_7> T_9> T_{11}> T_8> T_{12}. It data also revealed that cluster bean and cowpea based intercrop contribute most and blackgram based intercrop contribute lest phosphorus in soil." The available phosphorus the value ranged from 47.4 kg ha^{-1} to 64.3 kg ha^{-1}. The highest content of available phosphorous was observed in mango + Cluster bean intercropping (T_2) (64.3 kg ha^{-1}) subsequently in jackfruit + Cluster bean intercropping (T6) (57.6 kg ha^{-1}) and the minimum content of available phosphorus was observed in Cashewnut + Blackgram intercropping (T_{12}) (47.4 kg ha^{-1}). The improvement in available phosphorous content was because of legume intercrop root exudates solubilised the exchangeable phosphorus as well as increase the total microorganisms in rhizosphere particularly PSB (phosphorus solubilizing bacteria).

Available potassium: It was observed that available potassium content from fruit based agroforestry systems indicted higher values as compared to the initial status (144.1 kg per hectare). The maximum available potassium content was observed in under mango + cowpea system (T_3) (167.1 kg per hectare) then after jackfruit + cowpea system (T_7) (164.1 kg per hectare) and the lowest available potassium content was observed in under Cashewnut + Arhar system (T_9) (146 kg per hectare). The available potassium trend from highest to lowest was: T_3> T_7> T4> T11> T_8> T_2> T_6> T_{12}> T_{10}> T_1> T_5> T_9. It data also revealed that cowpea and blackgram based intercrop contribute most and arhar based intercrop contribute lest potassium in soil. (Table 2) The content of available potassium values under fruit based agroforestry systems ranged from 146 kg ha^{-1} to 165.2 kg ha^{-1} (Table 2). The highest content of available potassium was found in mango + cowpea intercropping (T_3) (167.1 kg ha^{-1}) subsequently in jackfruit + cowpea system (T_7) (164.1 kg ha^{-1}) and the minimum content of available potassium was observed in under Cashewnut + Arhar intercropping (T_9) (146 kg ha^{-1}). This might be because of more uptake of potassium by arhar and less uptake by cowpea.

Table 3. Soil organic carbon change and carbon sequestration status under fruit based agroforestry system (2015 - 2021).

Treatments	Soil organic carbon on 2015 (g kg^{-1})	Soil organic carbon after harvesting of legume crops in 2021 (g kg^{-1})	Difference in soil organic carbon status	Bulk density (BD) (Mg/m^3)	Organic carbon (%)	Soil depth (cm)	C sequestration of soil (Mg C/ha-year/season)
Mango+ Arhar :T_1	4.7	5.1	0.4	1.45	0.04	15	1.10
Mango+ Cluster bean :T_2	4.8	5.4	0.6	1.45	0.06	15	1.65
Mango+ Cowpea : T_3	4.7	5.9	1.2	1.45	0.12	15	3.13
Mango+ Blackgram :T_4	4.2	5.9	1.7	1.45	0.17	15	4.68
Jackfruit + Arhar :T_5	4.0	4.7	0.7	1.45	0.07	15	1.93
Jackfruit + Cluster bean :T_6	4.4	5.2	0.8	1.45	0.08	15	2.21
Jackfruit + Cowpea :T_7	4.7	5.7	1.0	1.45	0.10	15	2.76
Jackfruit + Blackgram :T_8	4.7	5.8	1.1	1.45	0.11	15	3.03
Cashewnut + Arhar :T_9	4.1	4.6	0.5	1.45	0.05	15	1.38
Cashewnut + Cluster bean :T^{10}	4.0	4.7	0.7	1.45	0.07	15	1.94
Cashewnut + Cowpea :T_{11}	4.4	5.3	0.9	1.45	0.09	15	2.48
Cashewnut + Blackgram :T_{12}	4.5	5.6	1.1	1.45	0.11	15	3.04
CD (0.05)	0.18	0.15	-	-	-	-	0.27

Soil organic carbon: The soil organic carbon of all the intercropping systems was found to be higher than their initial values. The maximum organic carbon change was observed in Mango+ Blackgram (T_4) (1.7 g kg^{-1}) followed by Mango+ Cowpea (T_3) (1.2 g kg^{-1}). (Table 3). Lowest organic carbon content change is found in Mango+ Arhar (T_1) (0.4 g kg^{-1}) followed Cashewnut + Arhar (T_9) (0.5 g kg^{-1}).The order of organic carbon change from highest to lowest was: $T_4 > T_3 > T_8 = T_{12} > T_7 > T_{11} > T_6 > T_{10} = T_5 > Tr_2 > T_9 > T_1$. The soil organic carbon of all the intercropping systems was found to be higher than their initial values. The maximum organic carbon change was observed in Mango+ Blackgram (T_4) (1.7 g kg^{-1}) followed by Mango+ Cowpea (T_3) (1.2 g kg^{-1}). Lowest organic carbon content change is found in Mango+ Arhar (T_1) (0.4 g kg^{-1}) followed Cashewnut + Arhar (T_9) (0.5 g kg^{-1}). Das *et. al*. (2013) found 18% lignin content in mango leaf that contributes for easy and quick decomposition of organic matter.

Carbon sequestration: It was observed that highest carbon sequestration in Mango+ Blackgram (T_4) (4.68 Mg C/ha-year) followed by Mango+ cowpea (T_3) (3.13 Mg C/ha-year). Lowest carbon sequestration change was found in Mango+ Arhar (T_1) (1.10 Mg C/ha-year) followed Cashewnut + Arhar (T_9) (1.38 Mg C/ha-year). (Table-3) The change of organic carbon from highest to lowest was: $T_4 > T_3 > T_8 = T_{12} > T_7 > T_{11} > T_6 > T_{10} = T_5 > T_2 > T_9 > T_1$.

It was observed that highest carbon sequestration in Mango+ Blackgram (T_4) (4.68 Mg C/ha-year) followed by Mango+ cowpea (T_3) (3.13 Mg C/ha-year). Lowest carbon sequestration change is found in Mango+ Arhar (T_1) (1.10 Mg C/ha-year) followed Cashewnut + Arhar (T_9) (1.38 Mg C/ha-year). The carbon sequestration potential of Agroforestry systems in India is estimated between 0.25 – 19.14 and 0.01 to 0.60 Mg C/ha/yr for tree and crop component, respectively (Dhyani *et al*. 2016).

Growth performance of fruit trees

Fruit tree heights : Data on fruit tree height was collected from 66 months old tree, from August 2020 to January 2021 and statistically evaluated and given below (Table 4), indicates that a significant variation was observed in total height of fruit trees under different intercropping combinations. Jackfruit + cowpea (T_7) exhibited highest total height (8.09 m) up to January after then Jackfruit + Blackgram (T_8) having height (7.32 m). Mango + arhar (T_1) exhibited the lowest total height (3.37 m) after then Mango + Cluster bean (T_2) (3.63 m). Out of mango based agroforestry system, Mango + Cowpea (T_3), Jackfruit

+ Cowpea (T_7) from jackfruit based intercropping system and Cashewnut + Cowpea (T_{11}) from Cashewnut based intercropping system, found highest height. The trends of total height of fruit trees were found as: T_7> T_8> T_6> T_5> T_{11}> T_3> T_9> T_4> T_{10}> T_{12}> T_2> T_1." Irrespective the intercrops, jackfruit has highest total height subsequently in Cashewnut and mango. This is might be because jackfruit has more growth in sapling stage as comprised to mango and cashewnut. Irrespective of woody species, the total height in trees in association with cowpea and blackgram was observed higher over cashewnut and arhar. It is shows that less competition gives by cowpea and blackgram for moisture, nutrient to fruit trees. The height of fruit trees with arhar was observed less, that might be because arhar gives more competition to fruit trees for different resources as arhar is a exhaustive crop with regards to water utilization, nutrient uptake and it's also have long growing duration as compared to other intercrops grown. Jackfruit + Blackgram (0.74 m) and Jackfruit + Cowpea (0.59 m) gives out higher height, which is might be because jackfruit have hereditary high growth rate as compare to cashewnut and mango as well as positive effect of cowpea and blackgram as intercrop. Similar trend also found by Rathore *et al.* (2013) and Swain (2014).

Collar girth: The maximum collar girth of 73 cm was observed in Cashewnut + Blackgram (T_{12}), followed by Jackfruit + Cowpea ($T_{7)}$ and the lowest collar girth of 43.99 cm observed in mango + arhar (T_1). Mango+ cowpea (T_3) from a mango-based intercropping system, jackfruit + cowpea (T_7) from a jackfruit-based intercropping system, and Cashewnut + blackgram (T_{12}) from a Cashewnut-based intercropping system got the grater collar girth. (Table 4). The collar girth trend at the end of 5th year was: T_{12}> T_7> T_{11}> T_8> T_{10}> T_9> T_6> Tr_5> T_3> T_4> T_2> T_1. "Regardless of intercrops, Cashewnut trees had a considerably larger collar girth than jackfruit trees. When compared to jackfruit and Cashewnut trees, mango trees generated considerably smaller collar girth in all combinations of intercrops. In terms of the effects of intercrops on fruit trees, blackgram and cowpea were shown to be more helpful than cluster bean and arhar. In compared to other intercrops, arhar had the least positive influence on collar girth. "The positive effect of blackgram and cowpea as intercrop has also been reported by Raut and Jain (2013), Mishra and Swain (2002)". The performance with arhar was relatively less its might be due to more competition between arhar and fruit trees as we know arhar is a exhaustive crop in comparison to the other crops grown. The difference in increment of collar girth in various combinations of intercrops and fruit trees its might be because of variation in growth rate of trees and get impact of legume crops. The high increment of girth observed in jackfruit and Cashewnut because it's has more growth of lateral meristem in 5th year as comparison to mango tree. The higher increment of collar girth under blackgram and cowpea was because of synergetic effect of cowpea and blackgram with fruit trees.

Crown spread: Under various combinations of fruit-based agroforestry systems, the crown width of 5th-year-old fruit trees varies significantly (Table 4). The crown width of cashewnut + blackgram (T_{12}) was significantly greater (7.69 m), followed by cashewnut + cowpea (T_{11}) (6.49 m). The crown width of mango + arhar (T_1) was the lowest (3.60 m). Mango+ cowpea (T_3) from a mango-based intercropping system, jackfruit + cowpea (T_7) from a jackfruit-based intercropping system, and cashewnut + cowpea (T_{11}) from a Cashewnut-based intercropping system were determined to be the most effective in term of increasing collar width. The crown width trend was observed as: T_{12}> T_{11}> T_{10}= T_7>T_9> T_8> T_6> T_3> T_5> T_4> T_2>T_1." Regardless of intercrops, Cashewnut produced substantially wider crowns than jackfruit and mango (Table 4). There was no difference among intercrops when it came to the impact of intercrops on the crown width of fruit trees. "Similarly, out of all fruit trees, Cashewnut gives out the maximum crown spread (7.69 m) subsequently in jackfruit and mango. In respect of interaction of fruit trees with intercrops no significant variation was observed. The values of crown spread gives out a clear cut difference at the end of fifth year's age. That is might be because of difference in genetic makeup among fruit trees with respect to crown spread. Cashewnut plants have more crown spread ability as compared to mango and jackfruit. The intercrops could not produce any a significant effect on the increment of crown spread of fruit trees."

Growth performance of legume crops: It was observed

Table 4. Growth performance of legume intercrops and fruit trees under fruit based Agroforestry system (Pool data of 2020 and 2021).

Fruit tree Species	Intercrops	Number of branches per legume plants	Legume plant height (cm) legume plants	Number of pods per	Tree height (m)	Collar girth (cm)	Crown spread (m)
	Arhar (T_1)	21.23	142.92	420.34	3.37	44.09	3.6
Mango	Cluster Bean (T_2)	23.76	60.02	64.85	3.63	46.59	3.76
	Cowpea (T_3)	5.67	62.72	13.42	3.92	54.23	4.45
	Blackgram (T_4)	5.85	60.02	17.67	3.71	49.37	4.2
	Arhar (T_5)	17.35	141.22	336.76	6.35	56.67	4.27
Jackfruit	Cluster Bean (T_6)	21.61	57.51	58.89	6.92	57.06	5.73
	Cowpea (T_7)	3.67	54.31	11.53	8.09	69.35	6.41
	Blackgrm (T_8)	5.01	57.51	16.11	7.32	61.47	6.07
	Arhar (T_9)	17.42	141.13	330.34	3.71	58.5	6.11
Cashewnut	Cluster Bean (T_{10})	21.83	58.52	59.65	3.64	60.71	6.41
	Cowpea (T_{11})	4.27	55.34	11.37	4.27	61.81	6.49
	Blackgram (T_{12})	5.21	58.52	16.25	3.58	73.00	7.69
Control	Arhar (T_{13})	20.31	142.42	422.84	0	0	0
(Sole intercrops)	Cluster Bean (T_{14})	24.72	60.39	66.81	0	0	0
	Cowpe (T_{15})	5.97	63.53	13.13	0	0	0
	Blackgram (T_{16})	5.91	60.39	17.72	0	0	0
CD (0.05)		0.47	5.33	1.21	1.24	14.14	1.96

that number of branches per plant significantly higher in cowpea sole crop as compare the other combination. In order to number of branches per plant; cowpea sole > T_3> T_{11} ¬> T_7 was observe in different stage of crop development. It might be due to shading effect of fruits trees. (Table 4). It was observed that plant height significantly higher in cowpea sole crop as compare the other combination. In order to plant height cowpea sole > T_3> T_{11} ¬> T_7 was observe in different stage of crop development. It was observed that number of pod per plant significantly higher in cowpea sole crop as compare the other combination. In order to number of pod per plant cowpea sole T_3> T_{11} ¬> T_7 was observe in different stage of crop development, which might be due to shading effect of fruits trees. It was observed that plant height significantly higher in Mango + Arhar (T_1) as compare the other combination. It was observed that number of branch per plant significantly higher in arhar sole crop as compare the other combination. In order to number of branch per plant T_1> T_{13} ¬> T_9> T5 was observe in different stage of crop development. It was observed that number of pod per plant significantly higher in Arhar sole crop as compare the other combination. (Dhara and Sharma 2015) Observed intercrop yield was less than sole and intercrop yields increased with increase in tree row spacing.

Yield and economics: Out of all intercrops the maximum legume yield was observed in mango + cluster bean system (8350 kg ha^{-1}) and the sole cluster bean was observed 8500 kg ha^{-1}. The performance of cluster bean was relatively better compared to other legume intercrops. Economics of all the fruit based agroforestry systems and open field grown crops were differed due to their difference in production. The gross return from intercrops significantly differs in fifth year of the fruit based agroforestry system. Arhar + cashew nut (T_9) gives out significantly highest gross return (Rs 73,060 ha^{-1}) as compare than others. Blackgram + Jackfruit (T_7) gives out significantly less gross return (Rs 24,960 ha^{-1}). The difference in gross return in intercrops is because of difference in yield and sale price. (Table 5) Out of the all intercrops the highest net return was observed in cashew nut + arhar (T_9) (Rs 51060 ha^{-1}) and the net return from its control was observed Rs 24242 ha^{-1}. The minimum net return was found in blackgram under jackfruit + blackgram system (T_7) (Rs 2960 ha^{-1}), the net return of control was observed Rs 9200 ha^{-1}. The difference due to different yield cost of cultivation and sale price (Table 5) The B: C ratio of the fruit based agroforestry system was observed low as compared to its controlled condition. In the fruit based agroforestry system, the range of B: C ratio differ from 1.13 to 3.32 and in control condition it differs from 1.41 to 2.21. The B: C ratio was observed highest (3.32) in the cashew nut + arhar system (T_9) as compared to its controlled

Table 5. Yield and economics of fruit trees and legume intercrops under fruit based agroforestry system (Pool data of 2020 - 2021).

Fruit tree species	Intercrops	Intercrops grain/green yield (kg/ha)	Fruit yield (kg / ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B : C Ratio
	Arhar (T_1)	740	430	59520	37520	2.70
Mango	Cluster Bean (T_2)	8350	290	42100	20100	1.91
	Cowpea (T_3)	1763	368	46300	24300	2.10
	Blackgram (T_4)	392	315	40810	18810	1.85
	Arhar (T_5)	595	0	37485	15485	1.70
Jackfruit	Cluster Bean (T_6)	7800	0	31200	9200	1.41
	Cowpea (T_7)	1274	0	25480	3480	1.15
	Blackgram (T_8)	312	0	24960	2960	1.13
	Arhar (T_9)	620	340	73060	51060	3.32
Cashewnut	Cluster Bean (T_{10})	8200	270	32800	10800	1.49
	Cowpea (T_{11})	1445	333	62200	40200	2.82
	Blackgram (T_{12})	326	300	26080	4080	1.18
Control	Arhar (T_{13})	734	0	46242	24242	2.10
(Sole Intercrops)	Cluster Bean (T_{14})	8500	0	34000	12000	1.54
	Cowpea (T_{15})	1775	0	35500	13500	1.61
	Blackgram (T_{16})	390	0	31200	9200	1.41
CD.(0.05)		117	0	4989	1463	

Crops	Sale rate (Rs/kg)	Crops	Sale rate (Rs/kg)
Arhar (grain)	63	Blackgram (grain)	80
Clusterbean (green)	4	Mango (ripe)	30
Cowpea (green)	20	Cashewnut (kernal)	100

condition (2.10). The lowest B: C ratio (1.13) found in jackfruit + blackgram (T_7). Intercrops not only give some seasonal return throughout the development phase of fruit tree, but they also aid in the enhancement of soil physico-chemical characteristics. (Table 5). Because the tree canopy was so low throughout the period, shade had no influence on the growth and economic production of these intercrops. (Arya *et al.* 2010) found that multi cropping outperformed sole cropping in terms of yield and economics.

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