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PHYSIOLOGICAL BEHAVIOUR AND YIELD EVALUATION OF COLOCASIA UNDER AGRI-HORTI-SILVICULTURE SYSTEM

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ABSTRACT: An agri-horti-silviculture model involving fruit trees, poplar (*Populus deltoides* Bartr. Ex Marsh.) as timber tree and colocasia were evaluated for yield and eco-physiological behaviours. Net photosynthesis, stomatal conductance and transpiration in colocasia were higher in pear × Kinnow combination than in highly shaded area of poplar ones. Colocasia showed better performance under partial shade in yield and yield contributing parameters, and decreased as canopy advanced in age. These parameters showed inverse relationship with canopy age and *vice versa* with more yield reduction under sixth year old canopy followed by preceding years and control. The transpiration (E) rate of colocasia was lowest under shade conditions irrespective of the crop used in the experiment leading to more water use efficiency in the shade conditions than in open. It is suggested that to minimize resource competition and improve physiological processes of crops, canopy management is essential to ensure better yield under pear-based agri-horti-silvicultural system.

Keywords : *Inter-cropping, colocasia, poplar, photosynthesis, stomatal conductance, shading effect, yield.*

Monoculture of rice-wheat rotation has not only devastated the agro-ecosystem, but is also responsible for the depletion of water table, over exploitation of nutrients, deterioration of soil structure, contamination of air, soil and water resources. The present situation demands diversification from the area under rice-wheat rotation to more annual remunerative field crops involving low farm inputs viz. irrigation, fertilizers, insecticides etc. Many alternatives including cultivation of horticultural crops have been suggested. But despite all efforts, area under horticulture crops is not escalating at faster rate as predicted by the policy planners. The major contributing factors responsible are shrinking of agricultural land, population pressure, shortage of water, high production cost, labour shortage, less cost benefit ratio, long juvenile period in fruit crops and poor soil health.

It is essential to develop some farming system models which should improve the economical status of farmers, provide the employment opportunities and support in the development of agro base industry in the region. It is necessary that agricultural land must be treated like a business unit which ultimately increases output in terms of biomass and evenly distributed annual income throughout the year. Above all, it is essential that the efficient land use system has to cater with the diverse needs of ever growing population such as food, fiber, fodder, fruit and timber. Obviously, such requirements can be fulfilled by an integrated farming system involving agriculture, horticulture, forestry and/or animal husbandry. The interactions between the various components like trees and fruit crops are very complex to understand. Broadly, such interactions can be classified as above and below ground level. This system of land use is called as "Agro-forestry". The interaction involves several bio-physical factors viz. tree-crop relations, light, space, water, nutrients etc. These balancing factors are the solutions for the success of Horti-silviculture system. Intercropping or mixed cropping has potential to increase total yields as compared with mono cropping using the same resources (Bellow, 2).

Diversification in traditional agriculture (rice–wheat rotation) has been getting high priority in the irrigated agro-ecosystem of North-western states of India due to many socio-economic and ecological problems i.e. insufficient storage space for wheat and rice, declining soil health, depleting underground water resources, indiscriminate use of agrochemicals etc. Farmers tried many alternative to rice-wheat rotation like other crops (oilseeds, cash crops, fruits and vegetables etc), poultry, fishery, piggery, dairy etc. but not much success was achieved because of inadequate marketing, technical and financial support (Chauhan and Mangat, 5). Recently, Punjab state has announced Diversification Policy, 2013 and they are also emphasizing to promote high value crops (maize, soya beans, sugarcane, cotton etc), fruits and vegetables crops. In this system, horticulture is emerging as one of the major growth engine in shifting area from wheat-paddy cultivation. Commercial orchard involves a high initial investment and monetary

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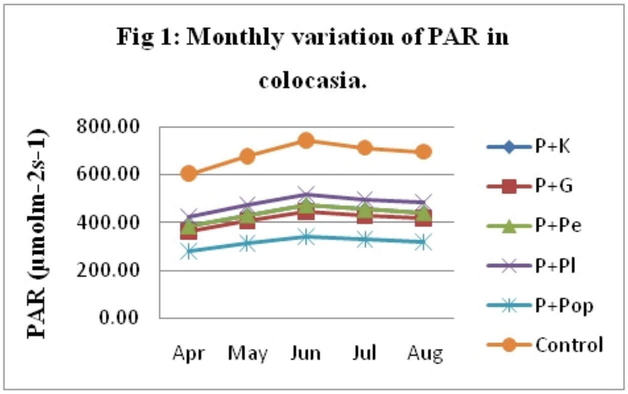
gain is possible only after particular time due to long juvenile period. During initial 3 to 4 years after their establishment, fruit tree develop appreciably low tree canopy and vacant space available between the rows and trees can be effectively utilized for growing various intercrops or short duration timber trees. This enhances the income of the orchardists during pre bearing stage and maintains soil health by altering physico-chemical properties of soil. Moreover the modifications in micro-environment due to growing of fruit trees directly or indirectly influence various vital physiological processes of the plants grown under tree canopy. Generally photosynthetically active radiation PAR and temperature are reduced, while the humidity is increased. Among these, PAR is important as the radiant energy captured by plants is utilized in the photosynthesis, which is the primary process governing biomass production and yield. Therefore, investigations on the physiological processes especially those related to photosynthesis are critical for understanding the plant growth under the canopy of trees (Chauhan *et al.,* 7). This article deals with the physiological response of under-story crops and biological/economic performance of turmeric under different fruit tree based multicropping system.

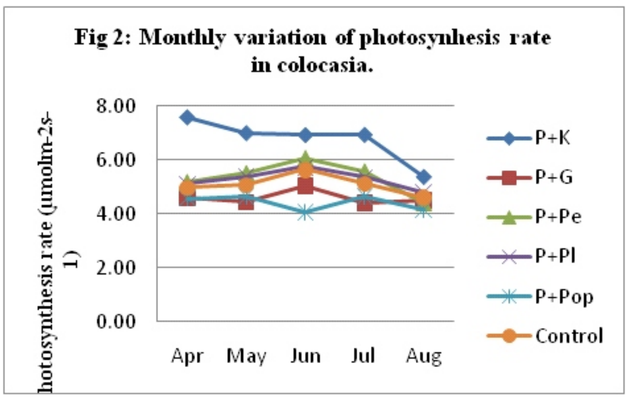
MATERIALS AND METHODS

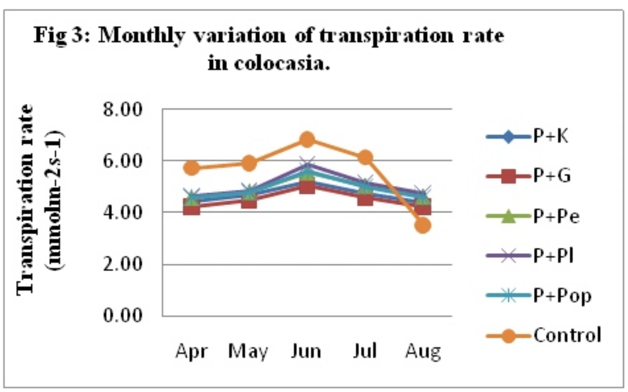
The experiment was conducted at New orchard of Department of Fruit Science, Punjab Agricultural University, Ludhiana, situated at latitude of 30.45^o N, longitude of 75.85^o E and at an altitude of 244 m above mean sea level. The climate is subtropical with dry season from October to first fortnight of June. The layout was prepared to accommodate different fruits and poplar plants between the recommended spacing of pear (6 m × 6 m) to make use of inter-spaces. The total area of experiment was accommodating 120 plants of pear and 30 plants of each fruit crop in intercropping with pear and 20 of under control conditions. Three replications in each combination were taken. Five-year-old fruit plants including peach cv. Shan-e-Punjab, plum cv. Satluj Purple, guava cv. Allahabad Safeda and Kinnow mandarin and poplar ETPs (Entire Trans Plants) were planted in between two pear plants in a row such that distance between pear and fruit tree is 3 m within row. Colocasia was sown in the end of February in the inter-row spaces of different intercropsplanted in north-south direction in completely randomized design with three replications. This experiment was laid out with the objective to evaluate interaction between different intercrops with colocasia. Control plots of colocasia with pear was also raised simultaneously for comparison. The statistical analysis was done with SAS. The data on yield and physiological parameters *viz.,* photosynthetic active radiation (PAR), stomatal conductance, intercellular CO_2 and transpiration rate, using portable photosynthesis system (CID 340, CID Inc., USA) on fully expanded leaves were recorded at 10.0 am, 1.0 pm and 4.0 pm at monthly intervals for both experimental as well as control plants. Water use efficiency was measured as ratio of net photosynthesis to transpiration with same units. The orchard soil was deep, well drained and loamy sand. All the trees received uniform and recommended doses of fertilizers and other cultural practices during the course of these investigations. The per cent light intercepted by tree was calculated as the reduction in the average light intensity under tree cover over control. The crop yield and yield contributing parameters were recorded on 1m × 1m quadrat basis to estimate the yield on acre basis and economics was worked out for comparison.

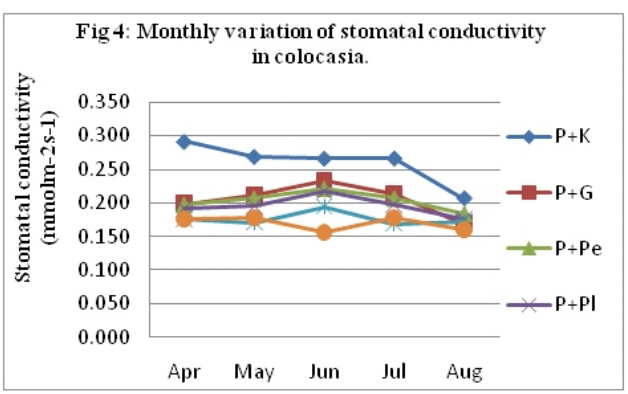
RESULTS AND DISCUSSION

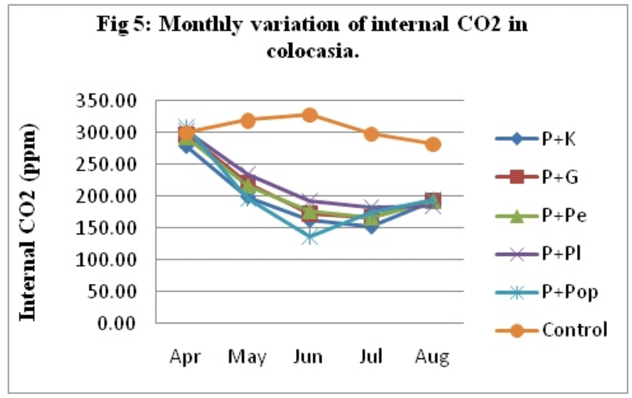
The effect of differential inter cropping system on eco physiological parameters was found to be significant irrespective of all the months (Table 1). Colocasia when grown under different crop combinations behaved differently as far as eco physiological parameters were concerned. Highest PAR (679.85 and 689.17 µmolm^{-2} s^{-1}) was observed by colocasia when grown with pear as single crop and it was significantly higher than all other combination during both the years followed by pear x plum (474.75 and 481.44 µmolm^{-2} s^{-1}) combination. Minimum PAR (313.10 and 317.57 µmolm^{-2} s^{-1}) was recorded by colocasia when it was grown under pear x poplar combination and it was significantly lower than all other combination. The colocasia grown under different inter crops showed varied light interception. All parameters *viz* net photosynthesis rate, water transpiration, stomatal conductance were greatly influenced by light interception and found higher in the pear x Kinnow except internal CO_2 which was higher in the open. Photosynthesis recorded maximum (5.77 and 5.75 µmolm^{-2} s^{-1}) in colocasia with pear x Kinnow during both the years and it was significantly higher than all other combinations including pear alone. At noon with the stress of high temperature and intense irradiation, net photosynthesis rate may decrease almost near to zero. It was primarily due to the reduction in the stomatal conductance which leads to short supply of CO_2. Photosynthesis was a physiological process that was affected by the environmental factors. All the under storey crops in general show changes in photosynthetic rate with a maximum photosynthetic activity during afternoon depending upon prevailing weather conditions during their growth period (Dhillon *et al.,* 9; and Chauhan *et al.,* 6).

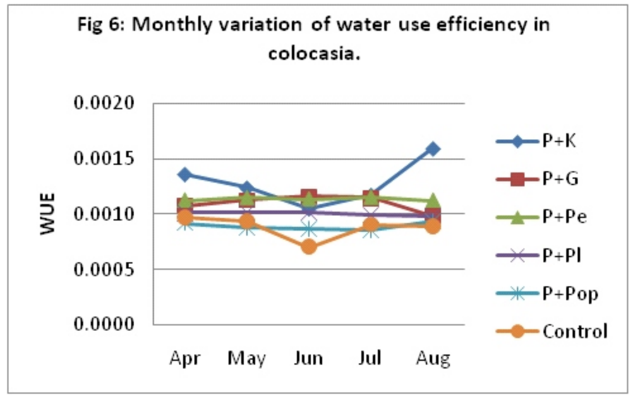


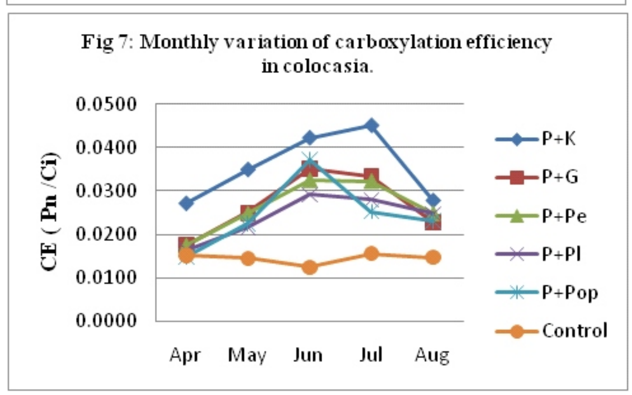












Minimum photosynthesis (4.42 and 4.39 µmol m^{-2} s^{-1}) was recorded with pear x poplar combinattion. It was mainly due to more interception of light and less availability of PAR which is the major contributing factor in photosynthesis. Transpiration recorded max in colocasia with pear alone (5.50 and 5.72 $mmolm^{-2}$ s^{-1}) and differ significantly with all other crop combinaton. Minmum transpiration rate (4.38 and 4.63 $mmolm^{-2}$ s^{-1}) was recorded with pear x poplar combination during both the year. The transpiration (E) rate was minimum under shade conditions irrespective of the fruit species used in the experiment leading to more water use efficiency under shade than in open. As far as stomatal conductance was concerned their value was recorded higher with pear x Kinnow intercrops and decreased in all other crop combination along with the decrease in photosynthesis during both the years. The stomatal conductance was found to decrease with increasing atmospheric temperature and decreasing relative humidity (RH) (Chauhan *et al.,* 7). Water use efficiency was recorded highest (0.0011 and 0.0011) in pear x Kinnow combination during both the years because of high photosynthesis rate with less transpiration and minimum was recorded in pear x poplar due to more interception of light by tree crops and resulted in to less photosynthesis.

However, intercellular CO_2 showed inverse relationship with photosynthesis and found maximum (307.09and 303.20 ppm) in calocasia grown with pear x poplar minimum intercellular carbon dioxide was observed in colocasia grown along under pear x Kinnow where photosynthetic rate was found to be highest. Carboxylation efficiency (0.0277 and 0.0308) which indicate the productivity potential was highest under pear x Kinnow and minimum (0.0202 and 0.0204) in calocosia grown under pear x poplar inter

Table 1: Eco-physiological parameters of colocasia grown under different intercrops.

Inter Crops	PAR ($\mu molm^{-2}s^{-1}$)		Photosynthesis (Pn) ($\mu mol\ m^{-2}s^{-1}$)		Transpiration ($mmol\ m^{-2}s^{-1}$)		Inter cellular carbondioxide Ci (ppm)		Stomatal Conductance ($mmolm^{-2}s^{-1}$)		Water use efficiency (WUE)		Carboxylation efficiency (*Pn/Ci*)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Pear × Kinnow	474.75^{b}	481.44^{b}	5.77^{a}	5.75^{a}	4.86^{c}	5.00^{c}	208.08^{d}	186.88^{d}	0.255^{a}	0.268^{a}	0.0112^{a}	0.0012^{a}	0.0277^{a}	0.0308^{a}
Pear × guava	409.21^{d}	415.04^{d}	4.52^{d}	4.52^{d}	4.57^{d}	4.77^{d}	223.04^{b}	216.56^{b}	0.199^{d}	0.216^{e}	0.0010^{c}	0.0010^{c}	0.0256^{d}	0.0282^{c}
Pear × peach	433.16^{C}	439.36^{c}	5.10^{b}	5.56^{b}	4.94^{b}	5.13^{b}	214.01^{cd}	189.55^{d}	0.225^{b}	0.259^{b}	0.0011^{b}	0.0011^{b}	0.0266^{b}	0.0294^{b}
Pear × plum	432.40^{c}	438.55^{c}	5.09^{b}	5.47^{c}	4.80^{c}	5.03^{c}	212.45^{cd}	205.11^{c}	0.224^{b}	0.255^{c}	0.0011^{b}	0.0011^{b}	0.0264^{bc}	0.0291^{b}
Pear × poplar	313.21^{e}	317.57^{e}	4.42^{e}	4.39^{f}	4.38^{e}	4.63^{e}	307.09^{a}	303.20^{a}	0.195^{e}	0.204^{f}	0.0009^{d}	0.0009^{d}	0.0202^{e}	0.0204^{d}
Pear alone	679.21^{a}	689.17^{a}	4.87^{c}	5.29^{d}	5.50^{a}	5.72^{a}	215.58^{c}	204.95^{c}	0.214^{c}	0.246^{d}	0.0009^{d}	0.009^{d}	0.0259^{dc}	0.0286^{c}
LSD5%	6.40	6.88	0.09	0.07	0.06	0.05	6.76	4.73	0.004	0.003	0.0001	0.0001	0.0005	0.0004
CV	3.36	3.57	4.22	3.20	3.09	2.54	7.05	5.21	4.22	3.20	5.62	4.30	4.30	3.75
Pr > F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Table 2: Diurnal variation in eco-physiological parameters of colocasia (Mean of all intercrops).

Timings	PAR ($\mu molm^{-2}s^{-1}$)		Photosynthesis (Pn) ($\mu molm^{-2}s^{-1}$)		Transpiration ($mmolm^{-2}s^{-1}$)		Inter cellular carbondioxide Ci (ppm)		Stomatal Conductance ($mmolm^{-2}s^{-1}$)		Water use efficiency (WUE)		Carboxylation efficiency (*Pn/Ci*)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
9-10 AM	396.00^{b}	397.24^{b}	4.89^{b}	5.01^{b}	4.49^{b}	4.66^{b}	208.45^{b}	199.53^{b}	0.216^{b}	0.233^{b}	0.0011^{a}	0.0010^{b}	0.0248	0.0261^{b}
1-2 PM	797.77^{a}	810.38^{a}	6.57^{a}	6.93^{a}	6.28^{a}	6.57^{a}	285.67^{a}	187.57^{c}	0.290^{a}	0.323^{a}	0.0011^{a}	0.0010^{a}	0.0384	0.0426^{a}
4-5 PM	177.45^{c}	182.95^{c}	3.43^{c}	3.61^{c}	3.76^{c}	3.91^{c}	196.01^{c}	266.03^{a}	0.151^{c}	0.168^{c}	0.0009^{b}	0.0009^{c}	0.0129	0.0145^{c}
LSD5%	4.53	4.87	0.06	0.05	0.04	0.04	4.78	3.34	0.003	0.002	–	–	0.0003	0.0003
CV	3.36	3.57	4.22	3.20	3.09	2.54	7.05	5.21	4.22	3.20	5.62	4.30	4.30	3.75
Pr > F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Table 3: Yield and yield related parameters of colocasia grown under different intercrops.

Inter Crops	Weight (g)			Size (cm)			Length (cm)			Yield (Q/acre)			Net income ₹/Acre		
	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean	2011	2012	Mean
Pear × Kinnow	32.45^{b}	28.73^{b}	30.59^{b}	3.36^{b}	3.09^{b}	3.23^{b}	9.18^{ab}	7.69^{b}	8.44^{ab}	40.12^{b}	36.36^{b}	38.24^{b}	23695^{b}	19619^{b}	21657^{b}
Pear × guava	30.73^{b}	27.84^{b}	29.29^{c}	3.37^{b}	2.94^{b}	3.16^{b}	8.79^{b}	7.70^{b}	8.25^{b}	37.15^{bc}	33.26^{bc}	35.20^{bc}	20474^{bc}	16249^{bc}	18361^{bc}
Pear × peach	28.44^{b}	26.99^{b}	27.72^{c}	2.94^{c}	2.68^{b}	2.81^{c}	7.58^{c}	6.21^{c}	6.90^{c}	35.85^{bc}	31.21^{bc}	33.53^{dc}	19062^{bc}	14023^{bc}	16542^{dc}
Pear × plum	31.15^{b}	28.37^{b}	29.76^{bc}	3.34^{b}	2.94^{b}	3.14^{b}	8.98^{ab}	7.41^{b}	8.20^{b}	39.92^{b}	36.14^{b}	38.03^{b}	23485^{b}	19373^{b}	21429^{b}
Pear × poplar	19.12^{c}	17.86^{c}	18.49^{d}	2.02^{d}	1.81^{c}	1.92^{d}	5.70^{d}	4.87^{d}	5.29^{d}	32.61^{c}	27.73^{c}	30.17^{d}	1553^{dc}	10247^{b}	12891^{d}
Pear alone	42.20^{a}	39.90^{a}	41.05^{a}	4.1^{a}	3.81^{a}	3.96^{a}	9.82^{a}	8.93^{a}	9.38^{a}	47.97^{a}	45.83^{a}	46.90^{a}	32220^{a}	29896^{a}	31085^{a}
LSD 5%	4.47	3.26	2.84	0.37	0.39	0.31	0.97	0.98	0.99	5.76	5.73	4.26	6265.7	6265.7	4631.8
CV	8.20	6.48	8.18	6.52	7.56	8.65	6.53	7.69	10.83	8.32	9.24	9.77	15.71	19.31	19.32
Pr > F	<.0001	<.0001	<.0001	<.0001	<.0001	<.001	<.0001	<.0001	<.0001	<.0018	<.0004	<.0001	<.0018	<.0004	<.0001

cropping system. In general carboxylation efficiency was significantly less in all the intercrop combinations as compared to pear x Kinnow. Maximum carboxylation efficiency of any crop indicates its higher productivity potential. *Pn/Ci* is positively correlated with stomatal conductance and water use efficiency indicating the usefulness of these traits for selecting plant genotypes for higher productivity under shade conditions. Carboxylation efficiency of under story crops declined with heavy shade as there was decline in photosynthesis in shade and also there was increase in inter-cellular carbon dioxide.

The diurnal variations in eco-physiological parameters viz. transpiration rate, photosynthetic rate and stomatal conductance was highest in afternoon during both the years. Photosynthetic Active Radiation (PAR) was significantly higher during afternoon with an average of about 797.77 and 810.38 μmolm^{-2} s^{-1} during 2011 and 2012 respectively. The least PAR was recorded during evening (4 pm) with 177.45 and 182.95 μmolm^{-2} s^{-1}. Irrespective of crop combinations & months, same trend was observed during both the years. Photosynthesis was found high (6.57 and 6.93 μmolm^{-2} s^{-1}) at afternoon which differ significantly from both morning and evening hours photosynthesis. Minimum photosynthesis (3.43 and 3.61 μmolm^{-2} s^{-1}) was recorded in evening hours. Reduction in solar radiation influences the physiological processes more importantly the photosynthesis. Plants responses to light include adaptation at physiological and biochemical levels (Wigington and Mcmillan, 20).Transpiration also showed the same results as shown by photosynthesis and found higher (6.28 and 6.57 mmolm^{-2} s^{-1}) at noon. Minimum transpiration rate (3.76 and 3.91 mmolm^{-2} s^{-1}) was recorded at the time of evening. Morning hour showed in between transpiration rate. However intercellular carbondioxide rate was found minimum at afternoon followed by mourning hours and maximum (285.67 and 187.57 ppm) was recorded in evening hours. Whereas stomatal conductance (0.290 and 0.323 mmolm^{-2} s^{-1}) was found higher at noon where photosynthesis rate was also high. Minimum (0.151 and 0.168 mmol m^{-2} s^{-1}) was noticed during evening hours. WUE was found maximum (0.0011) at the time of mourning and afternoon hours during both the years. Minimum WUE was observed at the time of evening hours due to less photosynthesis and more transpiration rate. The carboxylation efficiency was also highest (0.0384 and 0.0426) at afternoon and minimum (0.0129 and 0.0145) carboxylation efficiency was observed at evening during both the years. The difference between different intercropping system was mainly due to changes in microclimatic condition which ultimately affect the physiological processes in the under-story crops thus affecting the crop yield. PAR availability varies with the tree species and this in turn affects the growth and productivity of under story crop (Baig and Gill, 1).

The Photosynthetic Active Radiation (PAR) and transpiration rate were increased continuously Fig 1-7 and found highest in the month of June and decreased thereafter and recorded minimum in the month of August irrespective of crop combinations. However photosynthesis rate and stomatal conductance were recorded maximum in the month of April decreased thereafter and at par with each other in the months from May to July. i.e. Their value higher initially and later on decreased with maturity of leaves and recorded minimum in the months of August. Similarly Leech and Baker (13) observed that photosynthesis was low for young, rapidly expending leaves and maximum at some intermediate age, followed by a gradual decline as leaves aged. Water use efficiency was recorded significantly highest in the month of April and decreased thereafter and minimum was observed in the month of June and stable up to October. This is due to high rate of photosynthesis and low transpiration rate in the month of April thus indicating that the crops are able to efficiently utilize the water for fixation of CO_2 in initial growth phase and increase in transpiration rate thereafter. Mishra and Bhatt (14), while working with different *Leucaena leucocephala* genotypes under natural conditions in semi-arid tropics, reported similar results. Again it started increasing and found maximum in the month of August and decreased thereafter. This high WUE is mainly related with low transpiration rate in July-August due to high relative humidity in the environment. Carboxylation efficiency was also recorded significantly higher in the month of June and minimum was recorded in the month of August. Maximum carboxylation efficiency (*Pn/Ci*) is positively correlated with stomatal conductance.

Mean rhizome weight of colocasia was found maximum (41.05g) when it was grown along with pear as a single crop and differed significantly from all the other intercropping system. Minimum (18.49g) weight was recorded in colocasia grown under pear x poplar intercropping system. Same results were obtained during both the years under study. Size and length of the rhizome were also found significantly maximum (3.96cm and 9.38cm) when colocasia was grown under pear only and it decreased in all the crop combinations under study. Maximum decrease was noticed in pear x poplar intercropping system both for size (1.92) and length (5.29). As far as yield was concerned it was also found maximum (46.90q) in pear as a single crop and differed significantly as compared to all other intercropping system. Minimum yield (30.17q) was observed in pear x poplar intercropping system. The yield reduction was more under 6 year canopy (2012) as compared to 5 year canopy (2011) in all the crop combination. Similarly Gill *et al.* (11) also found the yield reduction in turmeric with the age of the intercrop plants increases. However quality is least affected under shade (Sarangi *et al.,* 18). Radiation is an important factor affecting crop photosynthesis, development and yield. Shade imposes a limitation on growth and development of crop plants but varies with shade tolerance of the crops. To avoid these losses, pruning of fruit plants should be done to reduce shading and also root pruned to reduce possible competition for water nutrients and light and increase crop yield in agro forestry systems (Gillespie, 12; and Rao *et al.,* 16). Availability of PAR under the canopy is crucial for vegetative as well as reproductive growth. Lower reduction in yield in colocasia under pear × Kinnow intercropping system in comparison to pear alone indicates suitability of rhizomatous crops under shade. The root crops respond well to the changed micro-climate under tree canopy i.e., soil/air temperature, relative humidity, light (quality/quantity), etc. Therefore, it is essential to promote light conditions under canopy through managing geometry of plantations or exerting judicious pruning and identification of suitable crops and their specific varieties under prevailing light conditions because when photon flux density decreases to approximately 40 per cent, the carbon assimilation becomes light limited (Cohen *et al.*, 8). The specific responses are also dependent on the arable crops (Burgess *et al.,* 3). As colocasia needs photoperiod (4-8 hrs) for production of better photosynthates and bulb production and soil moisture and temperature was also low in different intercropping system (Thakur *et al.,* 19). So yield was higher in intercrops having partial shade. But photosynthesis is a physiological process that is also affected by the environmental factors. All the under-storey crops in general show changes in photosynthetic rate with a maximum photosynthetic activity during afternoon depending upon prevailing weather conditions during their growth period. Proportional changes in photosynthesis rate in rhizomatous crops with available PAR have been reported earlier also, which was not observed in open condition so yield was low in pear × poplar intercropping system. Productivity cannot be criteria for the making comparison in different farming systems. Farmers itself will adopt the system on its economic sustainability. Therefore, an economic analysis was done to assess the viability of farming system. The income from colocasia was higher when grown with pear alone as compared to all other intercropping system. Colocasia though is less affected under shade but the additional income from the system makes the rotation more remunerative. The reduced yield of the crops under the tree canopy, lowers down the annual profitability margin than sole crop cultivation but the overall profitability of the intercropping system after tree harvesting is substantially high than traditional crop cultivation (Chandra, 4; Dhillon, 10), thus encourages the framers to invest in this sector and consider it a best performing low risk asset in near future.

CONCLUSION

It is thus concluded that the crop yield is certainly affected by the shade of the trees in tree-crop combinations but the resources use efficiency is better under trees than in open conditions. However, the productivity of colocasia is better in the combination than pure cropping. The eco-physiological parameters viz. PAR, photosynthesis, stomatal conductivity water use efficiency etc were found maximum with inter crop provide partial shade to the under canopy plants especially pear × Kinnow It is largely the economics, which determines whether tree-crop interventions are an opportunity or burden. In the changing climate scenario, tree-crop interface may be an adoption strategy and the carbon market may add to the profitability margins, which are yet not realized.

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