Influence of horti-silviculture combinations on pre-bearing growth and physiological parameters of pear

A.K. Sangwan, W.S. Dhillon*, H. Singh, N.P. Singh, S.K. Chohan and P.P.S. Gill
Department of Fruit Science, Punjab Agricultural University, Ludhiana 141 004

ABSTRACT

The present study was conducted to investigate the impact of different inter-crops on pre-bearing behavior of pear. Increment for rootstock diameter, plant height, plant spread and canopy volume were observed in different intercropping systems. There was significant effect of intercrops on growth of pear trees, except with poplar, where height and tree spread were significantly lower. Photosynthesis rate was higher in the trees with different intercrops than in the open conditions and maximum was recorded with Kinnow (7.44 µmol $m^{-2}s^{-1}$) and minimum with poplar (6.15 µmol $m^{-2}s^{-1}$). The rate of photosynthesis was more during morning and noon hours and least during afternoon during entire year.

Key words: Pear, diversification, stomatal conductance, photosynthesis, poplar, water use efficiency.

INTRODUCTION

Pear (*Pyrus* spp.) is an important pome fruit of the temperate region. However, due to the availability of low chilling varieties of hard, semi-soft and soft-pear its cultivation is gaining impetus in northern plains, some parts of N-E states and Niligiri hills of southern India. In Punjab, pear ranks fourth after citrus, guava and mango in terms of area and it covers an area of 2,707 ha with annual production of 59,992 Mt (Anon. 1). Pear fruit tree has long juvenile period therefore to earn additional income orchardists are growing more water demanding inter-crops like potato, *berseem*, spring maize etc. in winter but this practice disturbs the physiological activities in pear trees.

Fruit crops like Kinnow, guava, peach, plum, and timber crop poplar can be integrated with pear. They change the micro-environment, which affects growth and performance of trees by regulating various vital physiological processes (Tang, 14; Prado and Morasen, 9; Rodoglon and Teskey, 10). Intercropping or mixed cropping has potential to increase total yields above those of mono-cropping using the same resource base. The physiological processes of the crops like photosynthesis, water use efficiency and carboxylation efficiency under shade conditions are important factors. Growth variables like stock girth, scion girth and tree height were positively correlated with radiation flux, photosynthetic active radiation (PAR), stomatal conductance, inter-cellular CO_2 and transpiration rate (Dhillon *et al.*, 4,5). The stomatal conductance was found to decrease with an increase in atmospheric temperature and decrease in relative humidity (RH). Positive correlation of Pn/Ci with stomatal conductance and water use efficiency indicates the usefulness to select plant genotypes for higher productivity under shade conditions. Lack of quantitative yield data and understanding of tree-crop interactions are complex to understand. The present study was conducted with the objectives to understand the pre-bearing behavior of pear with different fruit crops and for identification of the pear-based suitable horti-silviculture model under sub-tropical Punjab conditions.

MATERIALS AND METHODS

The experiment was laid out at New Orchard of the Department of Fruit Science, PAU, Ludhiana, situated at latitude of 30.9° N, longitude of 75.85° E and at an altitude of 244 m above msl. 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 pear plants and 30 plants of each fruit crop as intercrops with pear and 20 pear plants as control (without any intercrop). Three replications for each plot with three plants per replication were selected. Fruit plants include peach cv. Shan-i-Punjab, plum cv. Satluj Purple, guava cv. Allahabad Safeda and Kinnow mandarin. Five-year-old fruit plants 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. This experiment was laid-out with the objective to evaluate interaction between pear with different fruit crops and poplar trees. Control plots of pear were also

*Corresponding author's present address: Punjab Horticultural Post-harvest Technology Centre, PAU campus, Ludhiana 141004; E-mail wasakhasingh@yahoo.com

raised simultaneously for comparison. The statistical analysis was done with SAS.

The data on vegetative growth attributes of pear trees were recorded five and six years after planting in December. The plants were planted during February in 2006. In pear, the vegetative growth parameters such as stock girth, scion girth and height of the plants were measured with the help of measuring tape in the month of January every year. Physiological parameters, *viz.*, photosynthetic active radiation (PAR), stomata conductance, intercellular CO_2 and transpiration rate, using portable photosynthesis system (CID 340, CID Inc., USA) on fully expanded leaves of the fruit crops 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. Organic carbon and NPK status were measured from upper 0-15 cm soil layer, litterfall was calculated at monthly interval and there total was done. 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 investigations.

RESULTS AND DISCUSSION

The data recorded for two years (2011 & 2012) revealed that the maximum mean tree height (3.72 and 4.08 m) of pear was under pear-Kinnow combination, which was statistically at par with pear plants grown along with guava. Whereas, the minimum plant height (3.24 and 3.50 m) was observed when pear plants were grown with poplar (Table 1). It was statistically at par with pear plants planted as a single crop. Contrast to above, the both way directions (North x South and East x West) the pear planted as a single crop produced highest plant spread. However, the data was non-significant when compared with pear planted along with Kinnow, guava and peach. Similarly, lowest plant spread in both the direction was observed when pear plants were grown along with poplar as compared to control plants. The data presented in Table 1 show that tree volume of pear plants positively correlated with the tree height. The maximum (2.42 and 3.72 m^3) height was observed under pear-Kinnow combination, which was statistically at par with pear plants grown in combination of guava, peach or as a single crop. The least plant volume (1.52 and 2.21 m^3) was observed when pear was grown with poplar, which was statistically at par with pear-plum combination. The maximum stock girth (135.63 and 164.73 cm) was recorded when pear was grown as a single crop that was statistically at par with pear grown in combination with Kinnow and guava. Significantly, lowest stock girth (112.37 and 133.68 cm) was noted when pear was grown along with poplar. Similarly, scion girth was also observed maximum (122.57 and 150.97 cm) when pear was grown as a single crop. It was statistically at par with pear when grown along with Kinnow and guava. Minimum plant scion girth (101.43 and 123.41 cm) was found when pear was grown along with poplar. Pear plants attained sufficient height with different fruit crops; hence, above ground bio-physical characteristics of the pear were not affected much by the fruit crops. Underground root competition of pear trees with that of other fruit crops for nutrient and water might have influenced the other growth characters of the pear trees. Kumar *et al.* (5) also tested eight intercrops to study the interaction for growth, yield and fruit quality of Santa Rosa plum and concluded that all these parameters were affected by the intercrops. Relatively high soil temperature would reduce the soil moisture and may conceivably contribute to lower soil organic matter and thereby adversely affect the growth of plants. Moreover, in the shaded area, the soil moisture was above wilting coefficient (10%) for most of the time (Singh *et al.*, 12). The results regarding different tree characters (tree length, tree spread, tree volume, stock girth and scion girth) obtained in present

Table 1. Effect of different intercrops on vegetative growth of pear.

Intercrop	Tree height (m)		Tree spread (m)				Tree volume (m^3)		Stock girth (cm)		Scion girth (cm)	
			North × South		East × West							
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Pear-Kinnow	3.72^a	4.08^a	1.10^a	1.31^a	1.12^a	1.32^a	2.42^a	3.72^a	133.72^a	161.88^a	121.08^a	149.38^a
Pear-guava	3.64^{ab}	3.98^{ab}	1.09^a	1.30^a	1.11^a	1.30^a	2.31^a	3.53^a	132.40^a	160.27^a	122.00^a	146.00^a
Pear-peach	3.55^{abc}	3.87^{bc}	1.05^{ab}	1.25^{ab}	1.07^{ab}	1.26^a	2.10^a	3.21^a	127.71^{ab}	152.14^a	113.88^{ab}	142.11^a
Pear-plum	3.47^{bc}	3.74^{cd}	1.02^{ab}	1.21^{ab}	1.05^{ab}	1.20^{ab}	1.95^{ab}	2.86^b	125.04^{ab}	151.55^a	115.62^{ab}	139.27^a
Pear-poplar	3.24^d	3.50^e	0.93^b	1.11^b	0.96^b	1.08^b	1.52^b	2.21^b	112.37^b	133.68^b	101.43^b	123.41^b
Control	3.39^{cd}	3.66^{de}	1.13^a	1.33^a	1.13^a	1.32^a	2.27^a	3.39^a	135.63^a	164.73^a	122.57^a	150.97^a
LSD ($P \leq 0.05$)	0.17	0.20	0.15	0.18	0.12	0.16	0.61	0.83	17.0	15.1	15.4	13.9

Values having same alphabets are non-significant with each other.

studies are in accordance with the finding of Nath *et al.* (8) and Singh and Rai (13) who concluded that these traits were better with inter-cropping system.

Increment in pear shoot length started in the month of March and continued up to August. No growth was observed thereafter up to February (Table 2). Maximum mean shoot length (37.19 and 34.63 cm) was recorded in the month of April, which was significantly higher than all the other treatment. Significantly, minimum shoot length during both the years (3.66 and 3.36 cm) was observed in the month of August irrespective of crop combination. This growth coincides with the active growth phase of pear and photosynthetic rate was also higher during these months and it decreased in October with maturity of leaves. As far as the effect of intercrops is concerned, the total maximum mean shoot length was observed when pear was planted with Kinnow that was statistically at par with guava and plum, and differed significantly. The pear showed comparatively higher photosynthetic rate (Tables 3 & 4) under pear-Kinnow and pear-guava intercropping as compared to pear grown with poplar and as a single crop. This indicates that pear could be better inter-planted with these crops, which provide partial shade to the main plant. Significantly, minimum shoot growth was observed in the pear intercropped with poplar.

The vegetative character, *viz.*, shoot length was greatly influenced by the environmental conditions like temperature that affect their development and growth. Thus, variation observed in the present study might be due to change in micro-climate. In general, organic matter and NPK status increased in all the crop combinations after six year of planting (Table 5). Organic matter, nitrogen, phosphorus and potash were found significantly higher with pear-poplar combination and minimum increase was observed with pear as sole crop. This might be due to litter-fall and their subsequent decomposition in the soil. Which is also observed significantly higher (605.22 g/m^2) in pear-poplar followed by pear-Kinnow combinations. Singh and Sharma (11) also reported that on account of recycling of organic matter, higher organic carbon percentage was observed in the soil under an intercropped plantation than at a site without trees and this high organic carbon influence the vegetative growth of plants.

The photosynthetic active radiation (PAR) and transpiration rate increased continuously and found highest in June and decreased thereafter. Minimum was noted in October irrespective of crop combinations. However, photosynthesis rate and stomatal conductance were recorded higher and at par with each other in the months from April to August that were significantly higher than all other months. Their value increased initially and later on decreased with maturity of leaves and recorded minimum in October. Similarly, Leech and Baker (6) observed that photosynthesis was low for young, rapidly expanding 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. While, minimum was observed during June. This may be due to high rate of photosynthetic and low transpiration rates during 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 (7), while working with different *Leucaena leucocephala* genotypes under natural conditions in semi-arid tropics, reported similar results. There was an increase which reached maximum during August and decreased later on. This high WUE is mainly related with low transpiration rate in July-

Table 2. Effect of different intercrops on shoot length (cm) of pear.

Month	2011							2012						
	Pear-Kinnow	Pear-guava	Pear-peach	Pear-plum	Pear-poplar	Control	Mean	Pear-Kinnow	Pear-guava	Pear-peach	Pear-plum	Pear-poplar	Control	Mean
Mar	17.56	15.60	13.31	14.45	13.23	14.13	14.71^c	17.93	16.38	14.08	15.07	13.86	14.69	15.95^c
Apr	42.58	35.62	38.49	36.70	32.67	37.11	37.19^a	41.35	34.14	37.21	35.58	31.15	36.05	34.63^a
May	20.17	22.86	23.33	22.36	20.34	21.17	21.70^b	19.28	21.14	22.34	21.37	18.83	20.40	19.41^b
June	9.56	12.51	11.97	14.68	8.15	12.38	11.54^d	10.47	12.85	12.25	13.87	8.88	11.82	11.83^d
July	8.64	8.07	7.78	7.11	6.32	6.59	7.42^e	8.98	7.69	8.05	7.04	6.06	6.89	7.47^e
Aug	4.24	3.77	3.13	3.97	3.12	3.78	3.66^f	4.01	3.96	3.09	3.65	2.89	3.51	3.36^f
Mean	17.12^a	16.40^{ab}	16.33^b	16.54^{ab}	13.97^c	15.86^b		16.88a	15.64^{bc}	16.00^b	15.64^{bc}	13.25^d	15.25^c	
LSD (P≤0.05)				Crop = 0.78 Time = 0.78 C × T = 1.02							Crop = 0.45 Time = 0.46 C × T = 0.94			

Values having same alphabets are non-significant with each other.

Table 3. Eco-physiological parameters recorded in pre-bearing pear grown under different intercrop combinations during growth period.

Month	PAR (μmol $m^{-2}s^{-1}$)		Photosynthesis (Pn) (μmol $m^{-2}s^{-1}$)		Transpiration (mmol $m^{-2}s^{-1}$)		Inter-cellular carbondioxide Ci (ppm)		Stomatal conductance (mmol $m^{-2}s^{-1}$)		Water use efficiency (WUE)		Carboxylation efficiency (Pn/Ci)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
April	416.35^{f}	437.71^{f}	6.99^{a}	7.22^{a}	2.54^{d}	2.81^{c}	295.60^{a}	294.09^{a}	0.287^{a}	0.296^{a}	0.0029^{a}	0.0027^{a}	0.0256^{c}	0.0272^{c}
May	483.09^{c}	473.54^{d}	6.92^{a}	7.20^{a}	2.94^{b}	2.81^{c}	266.07^{c}	284.59^{b}	0.284^{a}	0.296^{a}	0.0025^{b}	0.0027^{b}	0.0279^{b}	0.267^{c}
June	517.26^{a}	530.87^{a}	6.80^{a}	6.88^{a}	3.48^{a}	3.78^{a}	234.18^{d}	214.17^{e}	0.279^{a}	0.283^{a}	0.0020^{e}	0.0019^{f}	0.0323^{a}	0.0364^{a}
July	503.50^{b}	503.21^{b}	6.80^{a}	7.23^{a}	2.88^{c}	3.17^{b}	277.27^{b}	265.88^{c}	0.279^{a}	0.297^{a}	0.0025^{b}	0.0024^{c}	0.0261^{c}	0.0302^{b}
Aug	485.87^{c}	494.68^{c}	6.83^{a}	7.24^{a}	2.47^{e}	2.79^{c}	299.50^{a}	295.61^{a}	0.281^{a}	0.297^{a}	0.0029^{a}	0.0027^{a}	0.0238^{d}	0.0265^{c}
Sept	475.85^{d}	476.56^{d}	6.58^{b}	6.72^{b}	2.91^{cb}	3.21^{b}	263.20^{c}	253.39^{d}	0.270^{b}	0.276^{b}	0.0023^{c}	0.0022^{d}	0.0276^{b}	0.0304^{b}
Oct	454.30^{e}	462.77^{e}	5.25^{c}	5.52^{c}	2.51^{ed}	2.82^{c}	302.20^{a}	283.74^{b}	0.215^{c}	0.227^{c}	0.0022^{d}	0.0021^{e}	0.0190^{e}	0.0213^{d}
LSD ($P \leq 0.05$)	6.06	6.10	0.07	0.06	0.05	0.4	8.55	7.88	0.0029	0.0027	0.0001	0.0001	0.0009	0.0009

Values having same alphabets are non-significant with each other.

Table 4. Eco-physiological parameters recorded in pear grown under different intercropping systems.

Intercrop	PAR (μmol $m^{-2}s^{-1}$)		Photosynthesis (Pn) (μmol $m^{-2}s^{-1}$)		Transpiration (mmol $m^{-2}s^{-1}$)		Inter cellular carbondioxide (Ci) (ppm)		Stomatal conductance (mmol $m^{-2}s^{-1}$)		Water use efficiency (WUE)		Carboxylation efficiency (Pn/Ci)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
Pear-Kinnow	444.23^{d}	449.89^{d}	7.03^{a}	7.44^{a}	2.60^{d}	2.81^{d}	248.43^{d}	224.09^{f}	0.289^{a}	0.306^{a}	0.0028^{b}	0.0027^{b}	0.0249^{c}	0.0266^{b}
Pear-guava	432.03^{e}	437.71^{e}	6.90^{b}	7.31^{b}	2.40^{f}	2.66^{e}	262.81^{c}	241.69^{e}	0.283^{b}	0.300^{b}	0.0030^{a}	0.0029^{a}	0.0264^{b}	0.0272^{b}
Pear-peach	450.14^{c}	456.09^{c}	6.63^{c}	7.14^{c}	2.81^{c}	3.07^{c}	277.34^{b}	295.32^{b}	0.272^{c}	0.293^{c}	0.0025^{c}	0.0024^{c}	0.0286^{a}	0.0339^{a}
Pear-plum	484.74^{b}	491.01^{b}	6.30^{d}	6.51^{e}	2.98^{b}	3.22^{b}	296.61^{a}	286.53^{c}	0.259^{d}	0.267^{e}	0.0022^{d}	0.0021^{e}	0.0289^{a}	0.0337^{a}
Pear-poplar	364.78^{f}	369.60^{f}	6.15^{e}	6.14^{f}	2.49^{e}	2.67^{e}	302.26^{a}	305.92^{a}	0.253^{e}	0.252^{f}	0.0025^{c}	0.0023^{d}	0.0220^{d}	0.0235^{d}
Control	683.68^{a}	692.28^{a}	6.57^{c}	6.60^{d}	3.63^{a}	3.91^{a}	273.72^{b}	267.72^{d}	0.270^{c}	0.271^{d}	0.0018^{e}	0.0017^{f}	0.0255^{c}	0.0255^{c}
LSD ($P \leq 0.05$)	5.61	5.65	0.066	0.0605	0.052	0.046	7.91	7.29	0.0027	0.0025	0.0001	0.0001	0.0008	0.0008

Values having same alphabets are non-significant with each other.

Table 5. Effect of different intercrops on soil physical and chemical properties in pear.

Treatment	Organic carbon (%)	Nitrogen (kg/ha)	Phosphorus (kg/ha)	Potash (kg/ha)	Litter fall (g/m^2)
Initial status	0.46[c]	262.62[e]	132.51[c]	14.77c	-
Pear-Kinnow	0.64[ab]	345.62[b]	147.64[a]	18.59[ab]	405.37[b]
Pear-guava	0.61[ab]	338.49[b]	146.88[a]	18.66[ab]	399.17[b]
Pear-peach	0.57[b]	302.78[c]	146.66[a]	19.50[a]	385.26[bc]
Pear-plum	0.55[b]	274.21[de]	143.19[b]	17.10[b]	373.51[c]
Pear-poplar	0.69[a]	365.62[a]	149.44[a]	20.92[a]	605.22[a]
Control	0.55[bc]	268.49[de]	143.33[b]	17.00[b]	364.65[c]
LSD ($P \leq 0.05$)	0.09	17.44	3.25	2.60	22.47

Values having same alphabets are non-significant with each other.

August due to high relative humidity in the environment. Carboxylation efficiency was also recorded significantly higher in June and minimum was recorded in October. Maximum carboxylation efficiency (Pn/Ci) is positively correlated with stomatal conductance.

The effect of differential inter-cropping systems on eco-physiological parameters was found to be significant irrespective of months and PAR was recorded significantly highest (683.68 and 692.28 μmol m^{-2}s^{-1}) in pear when planted as alone during entire growth period as compared to other combinations. Minimum PAR (364.78 and 369.60 μmol m^{-2}s^{-1}) was recorded by pear plants under pear-poplar intercropping system in all the months. As PAR depend upon the interception of light by the plants so found maximum in pear alone and minimum in all the crop combinations. Photosynthesis is a physiological process that is affected by the environmental factors. The crops in general show daily changes in photosynthetic rate and a midday depression of photosynthesis depending upon prevailing weather conditions during their vegetative growth period. It was also evident from the Table 4 that photosynthesis was recorded highest (7.03 and 7.44 μmol m^{-2}s^{-1}) by the pear plants grown with Kinnow as compared to all other combinations. This might be due to the cuticular properties (waxy) affecting the availability of PAR because the more reflectance from the waxy layer of leaves. Minimum photosynthesis (6.15 and 6.14 μmol m^{-2}s^{-1}) was recorded in pear under pear-poplar intercropping system. It was happened because there was decline in photosynthesis under shade conditions (Chauhan *et al.*, 2). Similarly, stomatal conductivity was recorded highest (0.289 and 0.306 mmol m^{-2}s^{-1}) by the pear when grown along with Kinnow as compared to other combinations, which showed at par results with the pear-guava intercropping system. Minimum stomatal conductivity (0.253 and 0.252 mmol m^{-2}s^{-1}) was recorded in pear under pear-poplar intercropping system during both the years as it was directly correlated with the rate of photosynthesis. However, intercellular carbon-dioxide was recorded highest by the pear when grown along with poplar. Minimum intercellular carbon-dioxide was recorded by pear grown with Kinnow. Transpiration rate was recorded significantly highest by the pear plants when grown alone and in combination with plum during entire growth period. Minimum transpiration rate was recorded by pear under pear-poplar intercropping system. Maximum WUE was observed in intercropping system of pear-guava followed by pear-Kinnow and minimum was recorded in pear grown as sole crop and in combination with poplar. Maximum carboxylation efficiency was observed in the intercropping system of pear-plum followed by pear-peach and minimum was recorded in pear grown as a sole crop and in combination with poplar.

As-for-as diurnal variations (Fig. 1-4) was concerned, the maximum PAR was observed in pear at noon (898.72 μmol m^{-2}s^{-1}) during June and minimum (145.44 μmol m^{-2}s^{-1}) in evening during April. Generally, higher PAR was recorded at noon and the lowest during evening hours in all the months. Similarly, photosynthesis was observed maximum (8.98 μmol m^{-2}s^{-1}) at noon in April and minimum (2.89 μmol m^{-2}s^{-1}) during evening in October. Photosynthesis was recorded highest during noon as compared to morning and evening hours during all the months except in June, where it was recorded maximum in mourning hours. At noon with the stress of high temperature and intense irradiation, net photosynthetic rate was decreased almost near to zero. It was primarily due to the reduction in the stomatal conductance which led to short supply of CO_2. The stomatal conductance, was found to decrease with increasing atmospheric temperature and decreasing relative humidity (RH). The stomatal conductivity was observed maximum in May and June during morning and evening hours but

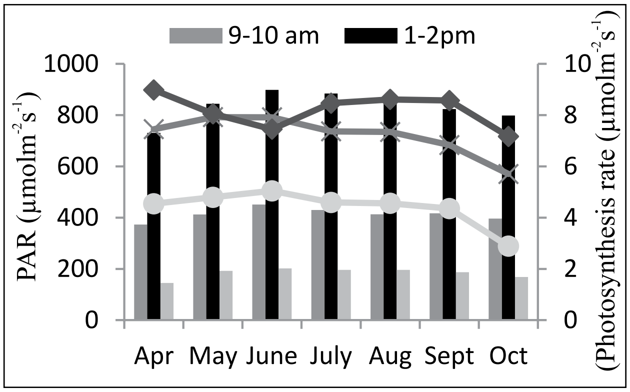

Fig. 1. Diurnal variation of PAR and photosynthesis in pear.

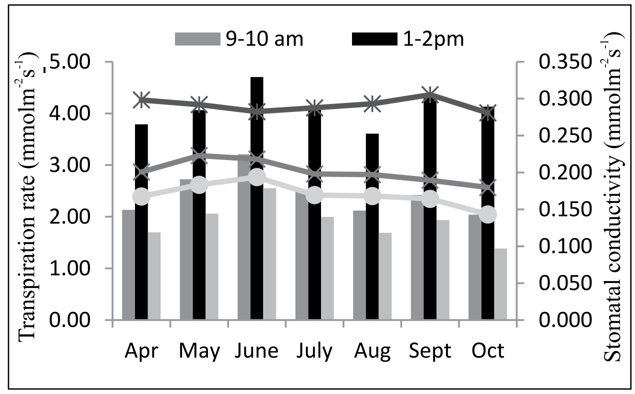

Fig. 2. Diurnal variation of transpiration rate and stomatal conductance in pear.

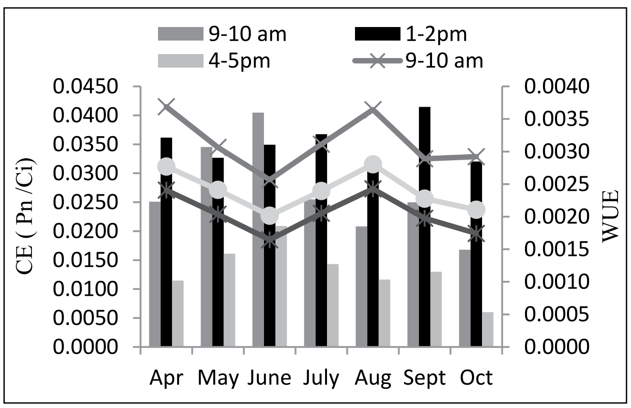

Fig. 3. Diurnal variation of caboxylation efficiency and WUE in pear.

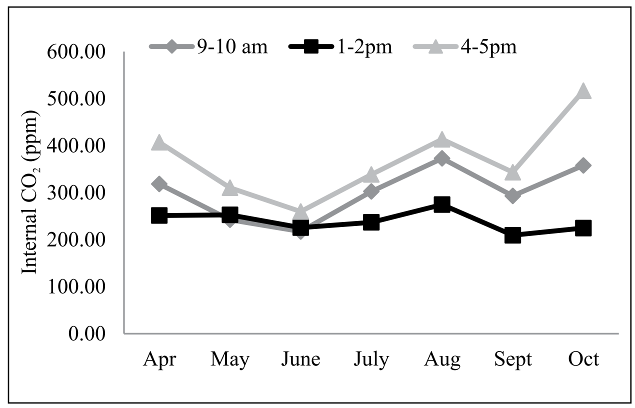

Fig. 4. Diurnal variation of internal CO_2 (Ci) in pear.

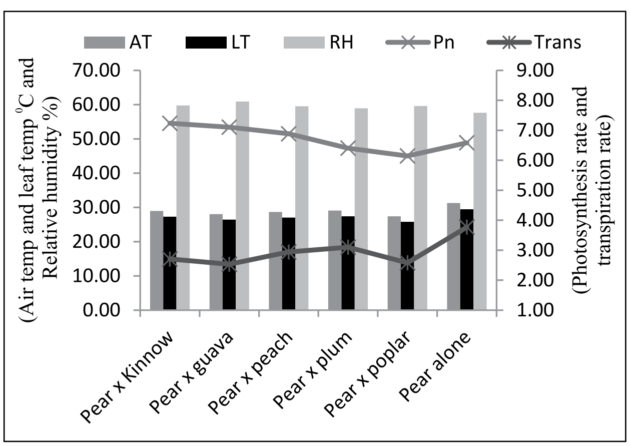

Fig. 5. Relationship between climatic and eco-physiological parameters.

lesser at noon. However, intercellular carbon dioxide was highest at evening and minimum was observed at noon during entire growth period. Transpiration rate was observed maximum at noon in all the crop combinations and minimum transpiration rate was observed during evening. Higher transpiration rate was recorded in the month of June and decreased thereafter, but this decrease was more in morning and evening hours as compared to noon up to October. However, WUE was observed maximum (0.0037) at mourning hours in April and minimum (0.0016) at noon in June. In general, less WUE was observed in June during all the times. This might be due to less photosynthesis at high temperature and higher transpiration rate. Carboxylation efficiency was observed higher at morning time in May and June, whereas, it was higher at noon in all the other months and minimum carboxylation efficiency was observed at evening hours. It was minimum during October. As PAR was dependent on the radiation received by the plants and all other parameters like photosynthesis, WUE, transpiration, stomatal conductance etc were interrelated with each other and varied in different intercropping systems according to the radiation received by the plants at that particular time. Likewise, Dhillon *et al.* (3) observed that photosynthetic rate was higher in the shade than in the open in fruit crops, namely, peach, Kinnow, plum and guava.

Air temperature of the canopy was found to be maximum (30.60 and 31.95°C), where pear was grown as a single crop and differed significantly from all other crop combinations (Fig. 5). There was reduction in canopy air temperature in all the crop combinations as compared to control and minimum (26.82 and 27.95°C) was noticed in pear-poplar combinations. Pear-guava also showed comparatively less canopy temperature as compared to all other combination. Maximum leaf temperate (28.78 and 30.13°C) was also noticed in pear grown as a sole crop followed by pear-Kinnow combination. Leaf temperature was recorded minimum in pear-poplar combination. Relative humidity was found maximum (62.82 and 58.96°C) in pear-guava intercropping system, which differs significantly from all other combinations. Minimum relative humidity (59.54%) was recorded in pear grown as sole crop. Photosynthesis was higher where leaf and air temperature was near about 26 and 28°C and it decreased above and below this temperature. Agro-forestry systems can modify the micro-climates and may help in maintaining the productivity of agricultural crops by lowering the under storey air temperature. Trees induce micro-climatic changes by reducing soil and air temperatures. These modifications directly influence the productivity of intercrops (Chauhan *et al.*, 2). The results are in conformity with the findings of Dhillon *et al.* (4). They studied micro-climate of the under storey crops measured in terms of photosynthetic active radiation (PAR), air temperature and relative humidity (RH) and reported that all these factors jointly affected the eco-physiology of the understory grown crops and thus their performance depending upon their adjustments to these conditions varied significantly than the open conditions.

REFERENCES

1. Anonymous. 2010. *Area and Production of Different Fruits in Punjab State,* Directorate of Horticulture, Punjab, Chandigarh.
2. Chauhan, S.K., Dhillon, W.S., Singh, N. and Sharma, R. 2013. Physiological behaviour and yield evaluation of agronomic crops under agri-horti-silviculture system. *Int. J. Plant Res.* **31**: 1-8.
3. Dhillon, W.S., Chohan, S.K., Singh, N., Rattan, C.S. and Singh, D. 2010. Pre-bearing behaviour of some fruit crops under horti-silviculture system. *Indian J. Hort.* **67**: 311-14.
4. Dhillon, W.S., Srinidhi, H.V. and Chohan, S.K. 2007. Eco-physiology of crops grown under poplar tree canopy. *APA News*, **30**: 11-12.
5. Kumar, J., Rana, S.S., Verma, H.S. and Parmar, D.K. 2001. Long-term effects of inter-crops on growth, yield and fruit quality of plum (*Prunus salicina*). *Indian J. Agric. Sci.* **17**: 687-90.
6. Leech, R.M. and Baker, N.R. 1983. The development of photosynthetic capacity in leaves. **In**: *The Growth and Functioning of Leaves*, J.E. Dale and F.L. Milthorpe (Eds.), Cambridge University Press, Cambridge, U.K, pp. 271-307.
7. Mishra, S. and Bhatt, R.K. 2003. Seasonal variation in photosynthesis, transpiration and stomatal conductance in promising genotype of *Leucaena leucocephala. Indian J. Agroforest.* **5**: 115-18.
8. Nath, V., Das, B., Yadav, M.S., Kumar, S. and Sikka, A.K. 2007. Guava a suitable crop for second floor in multi-cropping system in upland plateau of Eastern India. *Acta. Hort.* **735**: 277-95.
9. Prado, K.C.T. and Morasen, J. 1997. Photosynthetic capacity and specific leaf to mass in twenty woody species of Cerrado vegetation under field conditions. *Photosynthetica*, **33**: 103-12.
10. Rodoglon, K. and Teskey, R.O. 1997. Changes in rates of photosynthesis and respiration during needle development of loblolly pine. *Tree Physiol.* **17**: 485-88.
11. Singh, B. and Sharma, K.N. 2007. Tree growth and nutrient status of soil in a popular (*Populus deltoides*) based agroforestry system in Punjab, India. *Agroforest Syst.* **70**: 113-24.
12. Singh, K., Ram, P., Singh, A.K. and Hussain, A. 1988. Poplar (*Populus deltoides* Bartram Ex Marshall) in forest and agroforestry systems. *Indian Forest.* **114**: 814-18.
13. Singh, R.V. and Rai, M. 2003. Standardization of mango based cropping system for sustainable production. *J. Res. Birsa Agric. Univ.* **15**: 61-63.
14. Tang, T. 1996. Seasonal changes in photosynthesis. **In**: *Physiological Processes Limiting Plant Productivity*, C.B. Johnson (Ed.), Butterworths, London.
15. Xiao Bang, P., Yuan Ying, Z., Jing, C., Zai, Min, J. and Shuo, Xin, Z. 2009. Photosynthesis, growth and yield of soybean and maize in a tree-based agroforestry intercropping system on the Loess Plateau. *Agroforest. Syst.* **76**: 569-77.

Received : October, 2013; Revised : January, 2015;
Accepted : February, 2015