The Bioscan 13(1): 365-369, 2018 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.com

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

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KEYWORDS
Inter-Cropping
Onion
Poplar
Photosynthesis

Received on :
16.06.2017

Accepted on :
05.01.2018

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ABSTRACT
In agri-horti-silviculture model involving fruit trees, poplar (Populus deltoids Bartr. Ex Marsh) as timber tree and onion were evaluated for yield and eco-physiological parameters. Mean weight of *Kharif* and *rabi* onion was found maximum (62.59 and 69.57g) when it was grown along with pear as a single crop and differed significantly when grown under all other intercropping system. Minimum weight (43.61 and 50.35 g) was recorded under pear + poplar intercropping system. Average weight 60.2 g, size 5.17 cm and yield 61.54 Q/acre of Rabi onion was found higher as compared to Kharif onion due to more availability of congenial temperature and higher photosynthetic rate 5.74 $\mu molm^{-2}s^{-1}$for growths. Onion showed better performance under partial shade in yield and yield contributing parameters and decreased as canopy advanced in age. Net photosynthesis, stomatal conductance and transpiration in onion were higher in pear alone than in highly shaded area of pear + poplar intercropping system. Change in micro-climate and resultant effect on physiology, yield and economics of onion under canopy are presented in this paper. The transpiration (E) rate of onion 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.

INTRODUCTION

In agro-ecosystem of North-western states of India, diversification in traditional agriculture (rice–wheat rotation) required 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*. Experts and farmers tried many alternative to rice-wheat rotation like other crops (oilseeds, cash crops, fruits and vegetables *etc.*) poultry, fishery, piggery, diary etc. but not much success was achieved because of inadequate marketing, technical and financial support (Chahun and Mangat, 2006). Moreover agricultural crop inputs in India are subsidized (varies from state to state) and governments are under pressure to phase out the subsidies to reduce the fiscal burden. Therefore, farmers are looking for best alternative ghand fruit plants based integrated system with vegetables may be found remunerative than traditional crop rotations as quality is least affected under shade (Sarangi *et al.,* 2007). Recently, Punjab state has announced Diversification Policy, 2013 and they are also emphasizing on promotion of high value crops such as fruits and vegetables crops. In this system, horticulture may be emerged as one of the major growth engine in shifting area from paddy-wheat cultivation. However commercial orchard involves a high initial investment and monetary gain is possible only after the juvenile period is over which vary from 3-12 years in different crops. 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 influence various vital physiological processes of the plants directly or indirectly, grown under tree canopy. 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. As the specific responses are also dependent on the arable crops (Burgess *et al.,* 2004). Intercropping or mixed cropping has potential to increase total yields as compared with mono cropping using the same resources (Bellow 2004). 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 and is utilized in the photosynthesis, which is the primary process governing biomass production and yield. Therefore, investigations on the eco-physiological processes especially those related to photosynthesis are critical for understanding the plant growth under the canopy of trees (Chahun *et al.,* 2013). This paper deals with the physiological response of under-story crops and biological/economic performance of onion 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 30.45ºN, longitude of 75.85ºE 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. Different fruits and poplar plants were accommodated 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 and forest crop (Kinnow, guava, peach, plum, popular) intercrop with pear and 20 plants of pear were kept alone without any fruit or timber crops. Three replications in each combination were taken. Five-year-old fruit plants including peach cv. Shan-i-Punjab, plum cv. Satluj Purple, guava cv. Allahabad Safeda and Kinnow mandarin and poplar ETPs (Entire Trans Plants) were planted in between two rows of pear plants. Onion was transplanted in the first week of August (Kharif season) and in the mid of December (Rabi season) in the inter-row spaces of different intercrops planted in north-south direction in completely randomized design with three replications. The experiment was laid out to evaluate interaction of different intercrops with onion. Control plot of onion with pear alone was also grown simultaneously for comparison. The data of eco-physiological parameters *viz.,* photosynthetic active radiation (PAR), stomatal conductance, intercellular CO_2 and transpiration rate was taken by using portable photosynthesis system (CID 340, CID Inc., USA) on fully expanded leaves at 10.0 am, 1.0 pm and 4.0 pm at monthly intervals among all the combination. Water use efficiency was measured as ratio of net photosynthesis to transpiration rate with same units. All the crops received uniform and recommended doses of fertilizers and other cultural practices during the course of these investigations. The crop yield and yield contributing parameters were recorded on 1m x 1m quadrat basis to estimate the yield on acre basis and economics was worked out for comparison. The statistical analysis was done with (SAS 9.3).

RESULTS AND DISCUSSION

Mean weight, size and length of *Kharif* and *Rabi* onion was found maximum (62.59 g and 69.57 g, 5.51cm and 5.78 cm and 3.70 cm and 3.94 cm) when it was grown along with pear alone and differed significantly from all other intercropping system (Table 1). This reduction in weight, size and length was recorded maximum with pear+poplar followed by pear+guava and pear+Kinnow intercrops in both *Kharif* and Rabi onion as they have more shading effect during both the seasons. But this rate of decrease was recorded less with pear+plum and pear+peach during both the seasons and *Rabi* in particular as their leaf fall stage coincide with the growth period of Rabi onion and as a result less shading effect on *Rabi* onion as compare to *Kharif* onion. Average weight, size and length of *Rabi* onion was found higher as compared to *Kharif* onion under all the intercrops. It may be due to leaf shedding by either one or both of the inter crops during winter season and more photosynthetic activity by the plant. As far as yield was concerned it was also found maximum (62.17q and 68.58q) for *Kharif* and *Rabi* onion respectively in pear alone as compared to other intercrops followed by pear + plum combinations. Minimum yields (47.89q and 56.23q) were recorded in pear + poplar intercropping system. This variation in yield and related parameters are mainly due to the 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 2005). 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.,* 2005).

Onion when grown under different crop combinations behaves differently as far as Eco physiological parameters were concerned. Highest PAR (555.39 and 507.56) was observed in *Kharif* and *Rabi* onion when grown with pear as single crop and it was significantly higher than all other combination (Fig 1). Minimum PAR (402.01) was recorded by *Kharif* onion when it was grown with pear + poplar whereas in *Rabi* onion it was recorded minimum (428.63) when it was grown with pear + guava intercrops and it was significantly lower than all other combinations because during winter poplar shed their leaves. However, guava is evergreen in nature so interception of radiations are more in later case. It was also evident from the table that all parameters *viz* net photosynthesis rate (5.94 and 6.05), water transpiration and stomatal conductance were higher in the onion with pear alone. These parameters decrease in all intercrops during both the season but this decrease was more in *Kharif* onion as compared to *Rabi* onion (Fig 1-3). This may be due to the shading effect of leaves of these crop combinations during *Kharif* season but in *Rabi* season dormancy period of these intercrops coincide with the growth period of *Rabi* onion and as a result less shading effect on *Rabi* onion as compare to *Kharif* onion

Table1: Yield and yield related parameters of *Kharif* and *Rabi* Onion grown under different intercrops

Intercrops	Weight (g)		Length (cm)		Size (cm)		Yield (Q/acre)		Net income Rs/Acre	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
Pear + Kinnow	56.83ab	58.50bc	3.27b	3.30dc	5.07bc	5.19dc	58.69a	61.22bc	21363ab	22941bc
Pear + guava	48.25dc	51.34dc	2.88c	3.13d	4.68d	4.86d	52.72dc	58.90bc	17633dc	21493bc
Pear + peach	52.95bc	63.57ab	3.19c	3.51bc	5.00dc	5.38bc	56.18bc	61.86bc	19794bc	23338bc
Pear + plum	58.24ab	67.82a	3.44b	3.69ab	5.25b	5.56ab	60.52ab	62.48ab	22502ab	23727ab
Pear + poplar	43.61d	50.35d	2.18d	2.42e	3.98e	4.25e	47.89d	56.23c	14619d	19828c
Pear alone	62.59a	69.57a	3.70a	3.94a	5.51a	5.78a	62.17a	68.58a	23532a	27534a
mean	53.74	60.19	3.11	3.33	4.91	5.17	56.36	61.54	19907	23143
LSD5%	6.33	7.85	0.22	0.32	0.25	0.33	5.13	6.23	3201.1	3891.4
CV	10	11.07	6.16	8.29	4.47	5.45	7.71	8.59	13.63	14.26
Pr Ã F	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	0.0102	Â.0001	0.0102

Table 2 : Diurnal variation in Eco-physiological parameters of *Rabi* onion (Mean of all intercrops)

Intercrops	PAR (μmolm-²s-¹)		Photosynthesis (Pn) (μmolm-²s-¹)		Transpiration (mmolm-²s-¹)		Inter cellular carbondioxideCi (ppm)		Stomatal Cond uctance (mmolm-²s-¹)		Water use efficiency (Wue)		Carboxylation efficiency (Pn/Ci)	
	Kharif	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*	*Rabi*
9-10AM	466.93b	408.61b	5.79b	6.06b	3.11b	3.45b	269.67b	254.05b	0.274b	0.320b	0.0018b	0.00018a	0.0225b	0.0245b
1-2PM	790.18a	794.42a	6.86a	7.12a	4.04a	5.60a	215.77c	231.74c	0.324a	0.376a	0.0017c	0.0012c	0.0329a	0.0314a
4-5PM	204.19c	190.18c	3.40c	4.05c	1.71c	2.55c	301.48a	293.96a	0.161c	0.214c	0.0019a	0.0016b	0.0117c	0.0140c
mean	487.1	464.4	5.35	5.74	2.95	3.86	262.3	259.91	0.253	0.303	0.0018	0.0009	0.0223	0.0233
LSD5%	6.04	4.56	0.0495	0.053	0.0482	0.0398	3.96	7.61	0.0023	0.0028	NS	NS	0.0004	0.0006
CV	3.76	2.98	2.8	2.81	4.94	3.11	4.59	8.88	2.8	2.81	8.16	5.09	5.68	7.88
Pr Ã F	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001	Â.0001

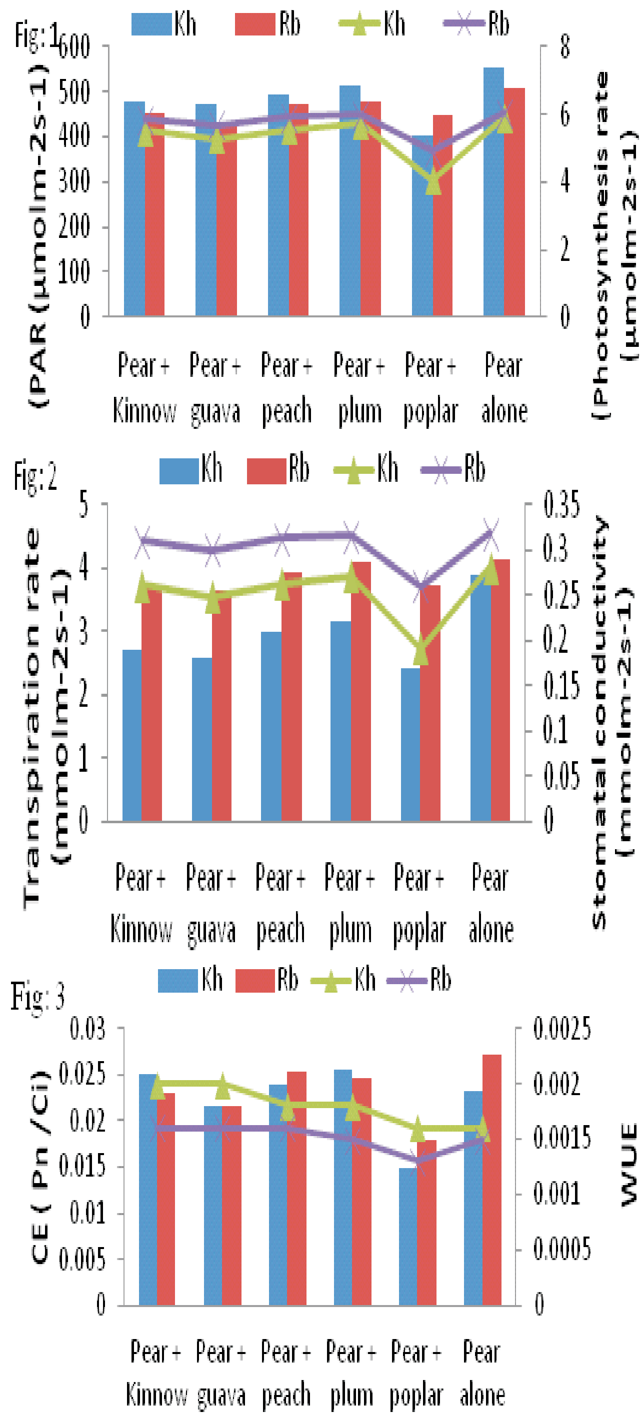

Figure 1-3 : Eco-physiological parameters of *Kharif* and *Rabi* Onion grown under different intercrops.

(Dhillon *et al.*, 2009 and Chauhan *et al.*, 2011). The stomatal conductance was found less in kharif as compare to rabi onion and this was directly related with increasing atmospheric temperature and decreasing relative humidity (RH) (Chauhan *et al.*, 2013). Water use efficiency was recorded highest (0.0020 and 0.0016) in pear + guava combination during both the years and minimum (0.0016 and 0.0013) was recorded in pear + poplar and pear alone. This high WUE was mainly due to less transpiration in case of pear + guava

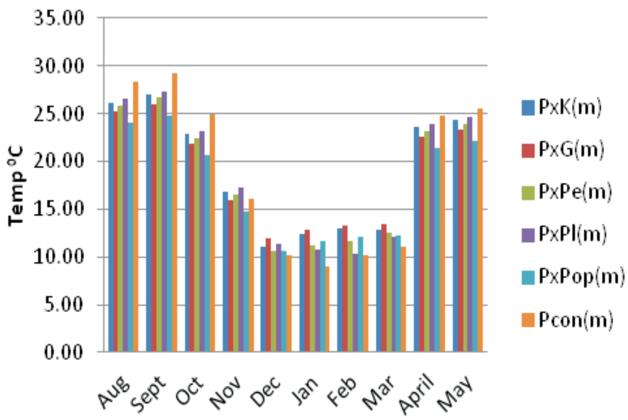

Figure 4 : Morning hours

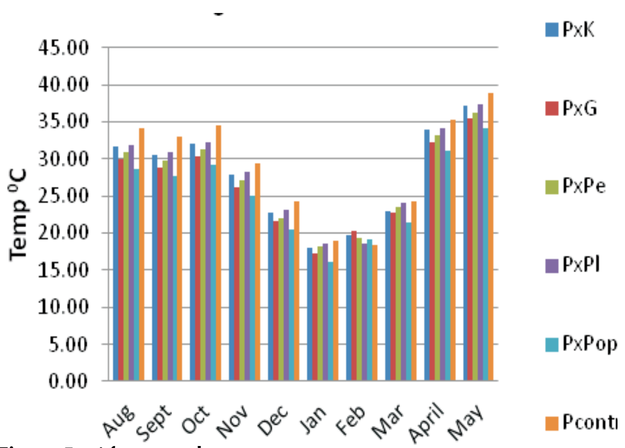

Figure 5 : Afternoon hours

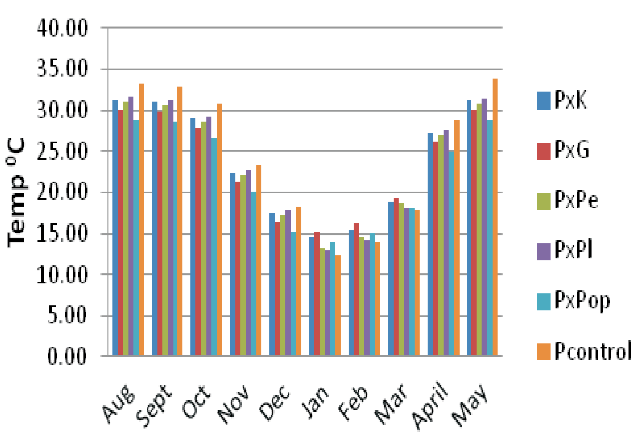

Figure 6: Evening hours

and due to more photosynthesis under open condition. Mishra and Bhatt 2003, while working with different *Leucaena leucocephala* genotypes under natural conditions in semi-arid tropics, reported similar results. Carboxylation efficiency (0.0261 and 0.0272) which indicate the productivity potential was highest in control where onion was grown along with the pear as a pure crop. In general carboxylation efficiency decreased in all the crop combination as compared to pure crop.

Diurnal Variation in various parameters like Photosynthetic Active Radiation (PAR), Transpiration rate, photosynthetic rate and stomatal conductance was highest during afternoon with an average of about 790.18 (µmolm-2s-1), 794.42 (µmolm-2s-1) during *Kharif* and *Rabi* seasons respectively (Table 2). The least PAR was recorded at the time of evening (4 pm) with 204.19 (µmolm-2s-1) and 190.18 (µmolm-2s-1) Irrespective of crop combinations & months. PAR was more in afternoon during *Rabi* season as compared to *Kharif*, however morning and evening hours PAR showed vice versa results. Which ultimately enhance the photosynthetic activity at afternoon in *Rabi* onion and found high (6.86and 7.12µmolm-2s-1) during *Kharif* and *Rabi* seasons which differ significantly from both morning and evening hours. As 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. It may be due to change in microclimate of the area by different intercrops which is clear from Fig. 4 to 6 that intercrops modify the microclimate differently at different timing of the day during different months. Morning time air temperature was observed minimum in pear grown as a pure crop from November to February and maximum in pear + guava intercropping system. In general morning hour's temperature was high in all the crops combinations as compared to pear as sole crop during these months. However in the remaining months temperature was higher in pear alone as compared to all other inter cropping system. It may be due to more availability of sun light under open field condition as compared to different intercrop system. But the afternoon temperature was maximum when pear was grown as a pure crop for the whole year and it was less in all the crop combinations. Similarly Thakur *et al.,* 2010 also recorded less moisture and temperature in different intercropping system as compare to sole crop.

However in evening hours minimum temperature was noticed in pear as a single crop and it increased with all the intercropping system. This may be due to the restriction of outward movement of short wave radiation from the soil due to the presence of dense canopy provided by high density planting in the intercropping system. This showed the effect of intercropping system on microclimatic conditions of crops. Sehgal *et al.* (2008) also reported that agroforestry systems can modify the micro-climates and may help in maintaining the productivity of agriculture crops by lowering the understorey air temperatures. These modifications directly influence the productivity of intercrops (Chauhan and Dhiman 2007). These results are in conformity with the findings of Dhillon *et al.* (2009, 2007).

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 agroforestry systems (Gillespie, 1989 and Rao *et al.,* 1998). The *Rabi* onion responded well to the changed micro-climate under tree canopy *i.e.*, soil/air temperature, relative humidity, light (quality/quantity), etc. But productivity cannot be the sole 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 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 2011, Dhillon *et al.,* 2007), thus encourages the framers to invest in this sector and consider it a best performing low risk asset in near future.

It is thus concluded that the crop yield is certainly affected by the shade of the trees in tree-crop combinations and the productivity of onion is better in the partial shade. The eco-physiological parameters *viz*. PAR, photosynthesis, stomatal conductivity, water use efficiency etc and yield of rabi onion was also found maximum with partial shade provided by sole crop in winter to the plants under canopy.

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