



## Appraisal of crop production in agri-horti-silvicultural system under arid-irrigated conditions of Punjab

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### ABSTRACT

In agri-horti-silvicultural model, the growth, yield and economic appraisal of intercropping of moong-chickpea rotation and turmeric was studied during 2014–18 under arid-irrigated conditions of Punjab. The model comprising one silvicultural crop (poplar), fruit crops (peach, plum, guava and citrus) and agronomic crops (moong-chickpea rotation and turmeric) were evaluated in different combinations. The moong-chickpea rotation and turmeric were also cultivated as sole crops for comparative analysis. The results revealed that the yield of all agronomic crops was the maximum under sole cropping leading to B:C ratio of 2.30 and 2.39 in moong-chickpea rotation and turmeric respectively followed by intercropping in poplar. Among different agri-silvi-horti combinations, the B:C ratio in system including deciduous fruit plants such as peach and plum was better as compared to evergreen fruit plants of guava and citrus. Cultivation of turmeric under different combinations was more beneficial than moong-chickpea crop rotation. Thus, it was concluded that during pre-bearing phase of fruit plants and before economic growth of poplar, the cultivation of turmeric is more profitable in agri-horti-silvicultural model. This model has potential for higher productivity of different crops in addition to natural resource conservation, efficient use of land and other resources.

**Key words:** Agri-horti-silviculture, Agronomic crops, Fruit crops, Inter-cropping, Poplar, Yield

The existing land use system with separate allocation to agriculture, horticulture and forest are inadequate to meet the ever increasing demand for diversified products such as food, fiber, fodder, fruit, timber etc. During the initial non-bearing life of fruit trees canopy is small and the vacant land in between the trees can be profitably utilized for the cultivation of harmless intercrops like fodder, agronomic crops, vegetables and pulses preferably of leguminous type or short duration timber trees under the horti-silviculture system which add to the income of the orchardists and sustain soil health by altering physico-chemical properties of soil (Dhillon *et al.* 2012). Poplar based agroforestry system has already been established as economically more viable and more profitable than any of the crop rotations under north western India. An efficient agroforestry system provides an economical and ecologically feasible opportunity for large scale diversification in agriculture on one hand and environmental amelioration on the other (Nayak *et al.* 2014). Intercropping of agricultural crops in horti-silviculture systems is of utmost importance for generation of early

and regular returns during the unprofitable period of a longer term crops. On-farm timber tree plantations can be also advantageous from the universal environmental amenities like carbon trading (Pandey 2007, Dogra 2007). Further, the tree based intercropping systems can result in more diversified economies for both, short and long term products from both agronomic and tree crops. The selection of intercropping components, however, must be based on the principle of minimizing the competition and maximizing the returns and should be site specific. Therefore, keeping these points in view, present study was carried out to find out suitable agronomic crops under fruit plants and poplar based horti-silviculture system.

### MATERIALS AND METHODS

The experiment was laid out at PAU, Regional Research Station, Bathinda located at 30° 11' N latitude and 75° 00' E longitudes at an elevation of 201 m amsl. The soil of experimental site was sandy loam, medium in available N (270 kg/ha), P (16 kg/ha), K (220 kg/ha), organic carbon content (0.65%) and slightly alkaline in reaction with pH 8.0. An agri-horti-silvicultural model comprising of poplar (*Populus deltoides* Bartr. Ex Marsh.) as timber tree, fruit trees (peach, guava, plum and citrus) and agronomic crops, viz. turmeric (*Curcuma longa* L.), moong (*Vigna radiata* L.) and chickpea (*Cicer arietinum* L.) were evaluated for growth parameters and yield during 2014–18. The plantation

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of poplar trees was carried out at a spacing of 6 m × 6 m in the north-south direction and either of four fruit crops, viz. peach cv. Shan-i-Punjab, guava cv. Allahabad Safeda, plum cv. Satluj Purple and Kinnow was planted in between the poplar tree. The understorey crops such as turmeric, moong were sown in the month of April in the inter-row space of poplar+fruit trees in randomized block design with three replications each. The moong crop was taken as summer crop and chickpea as *rabi* crop in sequence while turmeric was taken as one crop during the whole year. The plantation of sole crop of poplar and agronomic crops was also made for comparison. Data were recorded on vegetative growth of poplar and fruit trees while observations on yield per plant were recorded in agronomic crops to calculate the total yield of different crops under agri-silvi-horticultural system in comparison to control. Analysis of variance (ANOVA) and the test of mean comparison according to critical difference (CD) were applied. Significance level was accepted at  $P \leq 0.05$ . The data were analyzed by using CPCS1 software as a statistical analysis tool (Cheema and Singh 1990).

## RESULTS AND DISCUSSION

**Growth attributes of poplar tree:** The diameter of poplar at ground level and at 5 feet recorded linear increase from first year of growth to third year. The data presented in Fig 1A and 1B reveals there was no significant difference on growth of poplar with intercropping. In fact the growth of poplar in terms of diameter at ground height and at breast height as well as the tree height with intercropping was better than sole crop of poplar. This was probably due to the fact that soil status was better in intercropping due to regular irrigation, manuring and weeding. High production of wood in poplar when cultivated with seasonal agricultural crops due to the benefit drawn by the poplar plantations from various agricultural inputs like fertilizers, irrigation and proper management of soil have also been reported by Verma (2008). Chauhan and Mahey (2008) also reported higher returns in poplar with intercrops than sole crop of poplar.

**Vegetative growth of fruit crops:** The plant height (3.19 m) and canopy volume (20.05 m<sup>3</sup>) was significantly higher in citrus during the third year of study followed by guava while the minimum growth was observed in plum (Fig 2 A, B). Yadava *et al.* (2013) reported that all the trees in intercropping system showed significantly higher plant height over no intercropping. These results are also in close conformity with the findings of Banerjee and Dhara (2011) and Kumar *et al.* (2012) who reported that growth of fruit trees was better under agri-horti-silvicultural system than horti-silvicultural system alone.

**Days to maturity and yield of moong-chickpea rotation:** The number of days to maturity in moong crop did not vary significantly with various treatments in beginning of trial since the plant canopies were too small to have any shade effect. During second and third year of study, significantly less number of days to maturity in moong was observed in sole crop than all other treatments of horti-silviculture combinations (Table 1). Though no significant effect of different treatments on grain yield (kg/ha) was observed in first year of study, however, during the second and third year of study, a significantly higher grain yield (1181.0 kg/ha and 1200.8 kg/ha respectively) was observed in sole crop of moong. Further the grain yield in moong crop was significantly higher when grown in poplar alone as compared to other horti-silviculture combinations. Among different horti-silviculture combinations, the maximum grain yield (kg/ha) was observed in poplar + plum system while the minimum was recorded with poplar + citrus system.

The number of days to maturity and yield of chickpea did not differ significantly under the different treatment combinations during first year of study (Table 1). The number of days to maturity was recorded minimum in sole crop and vice-versa in poplar + citrus combination. During second and third year of study, the maximum yield was observed in sole crop which was at par with poplar alone. Among the different horti-silviculture combinations, the poplar + peach and poplar + plum systems recorded a significantly higher yield as compared to poplar + guava and poplar +

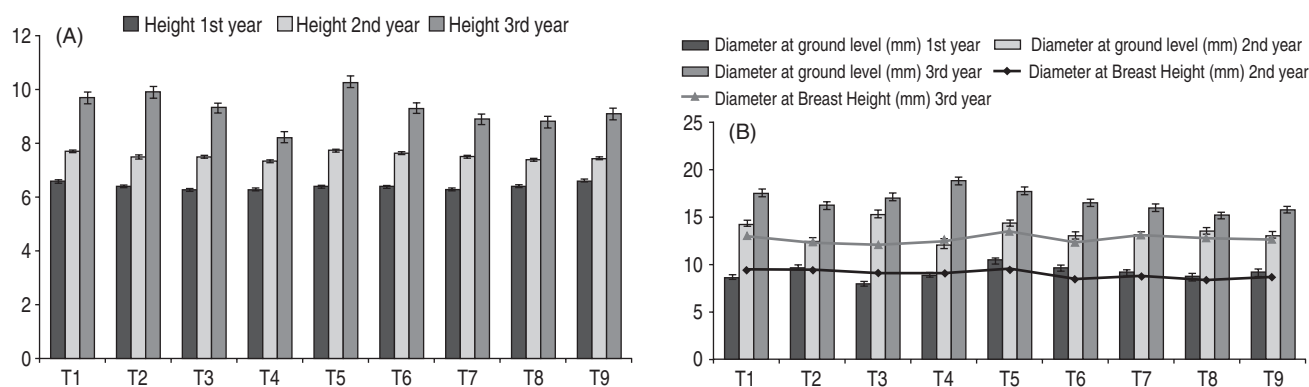


Fig 1 Vegetative growth parameters (A) height (m), (B) diameter at ground level (mm) and diameter at breast height of poplar in agri-horti-silviculture systems. T<sub>1</sub>, Poplar+Peach+Moong-Chickpea; T<sub>2</sub>, Poplar+Plum+Moong-Chickpea; T<sub>3</sub>, Poplar+Guava+Moong-Chickpea; T<sub>4</sub>, Poplar+Citrus+Moong-Chickpea; T<sub>5</sub>, Poplar+Peach+Turmeric; T<sub>6</sub>, Poplar+Plum+Turmeric; T<sub>7</sub>, Poplar+Guava+Turmeric; T<sub>8</sub>, Poplar+Citrus+Turmeric; T<sub>9</sub>, Sole Poplar.

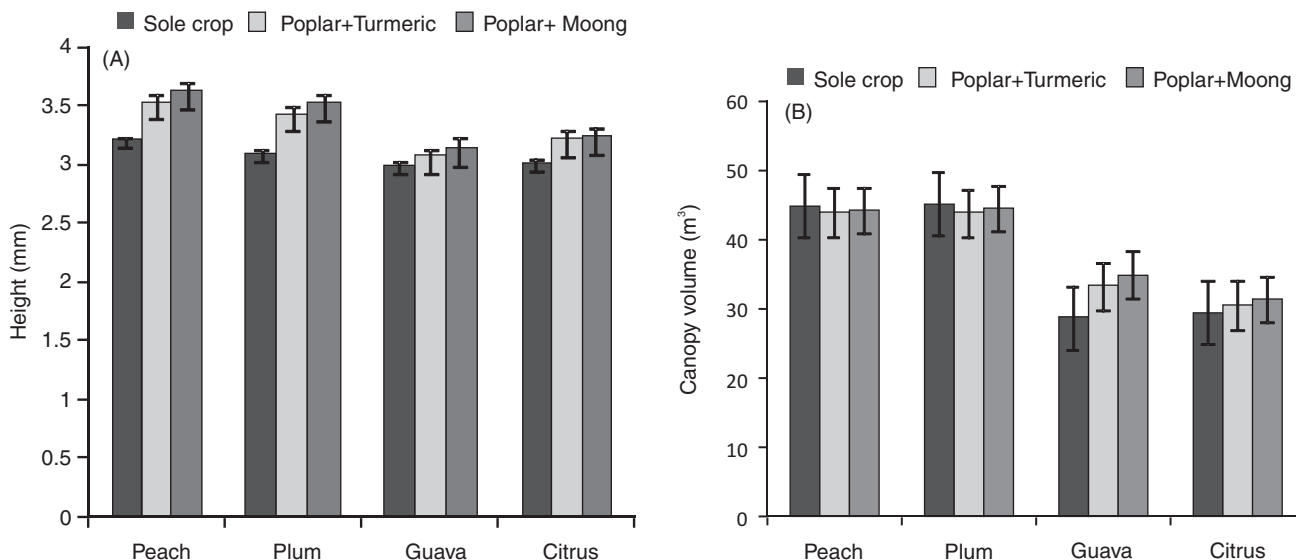


Fig 2 Vegetative growth parameters (A) height (m) and (B) canopy volume ( $m^3$ ) of fruit crops in agri-horti-silviculture systems.

Table 1 Effect of different horti-silviculture systems on Days to maturity and yield of moong and chickpea in moong chickpea rotation

Treatment	Moong						Chickpea						B:C ratio
	Days to maturity			Grain yield (kg/ha)			Days to maturity			Grain yield (kg/ha)			
	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year	
Poplar + Peach	77.67	78.57	78.85	939.3	848.9	802.4	148	147	154	968.7	856.0	841.5	1.62
Poplar + Plum	76.00	75.80	76.15	983.0	870.5	831.8	145	148	157	971.3	873.0	860.8	1.69
Poplar + Guava	77.00	75.97	77.10	973.3	847.0	798.5	143	159	161	865.7	730.0	711.2	1.46
Poplar + Citrus	77.33	77.27	78.25	935.7	827.9	785.1	149	157	163	850.7	728.3	705.1	1.42
Poplar	75.00	76.83	76.90	1016.3	993.5	981.2	145	145	148	985.3	873.3	861.2	1.85
Sole crop	73.33	71.73	72.50	1283.6	1181.0	1200.8	142	143	143	1024.3	936.0	958.3	2.30
LSD (P=0.05)	NS	4.54	3.90	NS	116	210	NS	5.2	5.0	70.23	87.00	92.5	-

citrus combinations. Higher yield of chickpea under peach and plum was due to their deciduous nature resulting in little shade effect on understory crop. The results are in corroboration with those of Sangwan *et al.* (2016) who observed that the deciduous nature of the trees resulting in shedding of leaves during winter, coinciding with the active growth period of garlic affected yield and related parameters positively. Thus, it was clear from the above observations that the higher shading effect of guava and citrus significantly resulted in yield reduction in chickpea crop. The reduction in crop yield under agroforestry systems was mainly due to the competition for the light, water, nutrients and allelopathic effect etc. Chauhan *et al.* (2013) observed that net photosynthesis, stomatal conductance and transpiration were higher in crops grown in open areas than in shaded ones. Similar variations in growth attributing parameters in annual crops under different agroforestry system have also been reported by Johar *et al.* (2017). In this kind of multistory agro-horti-silviculture system, the agricultural crop production is generally lower due to the competition with trees, but the biomass production is adequately compensated due to the overall productivity (tree

+ crop) which is generally greater than sole agricultural system (Newaj *et al.* 2003).

**Weight of rhizomes and yield of turmeric:** Weight of primary, secondary and tertiary rhizomes in turmeric crop was significantly higher in sole crop than other treatments in second and third year (Table 2). Among the different horti-silviculture combinations, the weight of primary, secondary and tertiary rhizomes was the maximum in poplar + plum combination which was at par with poplar + peach, while it was the minimum in poplar + citrus combination. Significantly higher yield of 142.2 q/ha and 144.3 q/ha of turmeric crop was recorded in sole crop during second and third year respectively, than other combinations. The yield of turmeric crop when planted in poplar alone gave a significantly higher yield of 138.9 q/ha and 138.1 q/ha during second and third year respectively than other horti-silviculture combinations. Among different horti-silviculture combinations, the maximum yield of turmeric crop was observed in poplar + plum which was statistically at par with poplar + peach combination. The minimum yield of turmeric crop was recorded with poplar + citrus during the second and third year of study. An earlier study by Gill *et*

Table 2 Effect of different horti-silviculture systems on weight of rhizomes/plant and yield of turmeric

Treatment	Weight of rhizomes/plant (g)									Yield of rhizomes (q/ha)			B:C ratio
	Primary			Secondary			Tertiary			1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> Year	
	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year	1 <sup>st</sup> year	2 <sup>nd</sup> year	3 <sup>rd</sup> year				
Poplar +Peach	45.8	44.1	43.8	31.4	31.3	30.1	6.0	5.3	5.0	142.1	135.9	134.3	2.24
Poplar +Plum	46.0	44.5	44.0	32.0	31.9	30.5	5.6	5.4	5.2	140.8	136.0	134.8	2.22
Poplar +Guava	48.1	43.0	42.8	30.9	32.4	29.8	5.7	5.2	4.9	143.8	135.6	134.0	2.23
Poplar +Citrus	44.6	42.4	41.1	30.2	32.7	29.1	5.3	5.1	4.9	142.0	135.5	133.5	2.21
Poplar	48.6	44.9	44.2	33.3	34.3	33.2	5.4	5.5	5.2	143.8	138.9	138.1	2.30
Sole crop	48.8	47.5	48.5	34.7	35.7	35.1	5.7	5.8	5.7	146.2	142.2	144.3	2.39
LSD (P=0.05)	NS	2.20	3.11	NS	1.21	1.58	NS	0.14	0.21	NS	2.60	3.65	-

al. (2009) revealed that fresh rhizome yield of turmeric decreased significantly as the age of poplar increases. The yield reduction in intercrops in later stages appears due to lesser availability of photosynthetically active radiation (PAR) transmitted through tree canopy. However yield reduction of crops in agroforestry system is not only due to shading effect of system but also due to sharing of other important resources like moisture, nutrient, space, etc. Below ground resources are more limiting than the above-ground resources in an arid environment that influences the growth and productivity of both tree and crops (Dalal *et al.* 2016). Bijalwan (2012) had reported the yield reduction in crops grown in association with fruit trees of apple, pear and peach after the age of 2- 3 years. Although sole crop cultivation is more remunerative than the crops under tree canopy, but mostly productivity of the intercropping system after tree harvesting is significantly higher than traditional crop cultivation (Dhillon *et al.* 2007, Chandra 2011).

The benefit cost ratio analysis of moong-chickpea rotation revealed that highest B:C ratio (2.30) was recorded in sole crops while under poplar canopy remunerative benefits with B:C ratio of 1.85 were observed (Table 1). Among different agri-horti-silvi combinations, the B:C ratio of deciduous fruit plants such as peach and plum was better as compared to evergreen fruit plants of guava and citrus. Deciduous plants cause less shade effect on agronomic crops under their plant canopies, resulting better yield of chickpea as compared to evergreen fruit plants. Although highest B:C ratio was obtained with turmeric as sole crop (2.39) followed by poplar-turmeric combination (2.30), but under different turmeric-fruit trees-poplar combination the B:C ratio was also ranges between 2.21 to 2.24 (Table 2). Cultivation of turmeric under different combination was more beneficial than moong-chickpea crop rotation. Profitability of poplar based agroforestry system has already been established in earlier reports (Chauhan *et al.* 2015, Rani *et al.* 2016). Also, once the fruit trees are in commercial bearing, it will add to the profitability margins, which were yet not realized at this stage.

It may be concluded that poplar + turmeric combination with deciduous fruit plants can profitably be adopted in arid irrigated conditions of Punjab. Such sort of venture

will be of multifarious utility to the farmers and also helps to enrich the soil health. Although, the yield of different agronomic crops was higher in sole crop cultivation followed by intercropping in poplar alone, but, the overall biomass production in different agri-silvi-horticultural system results in higher profits.

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