Tropical Agricultural Research Vol. 22 (2): 125 - 133 (2011)

Bioeconomic Appraisal of Flowering Annuals for Seed Production under Poplar (*Populus deltoides*) Based Agroforestry System

S. Rani, S.K. Chauhan[1*], R. Kumar and K.K. Dhatt[2]

Department of Forestry and Natural Resources
Punjab Agricultural University
Ludhiana, India

ABSTRACT. *To make the poplar (Populus deltoids) based agroforestry systems economically more profitable, twelve winter flower annuals under three environmental conditions (open, under 3 and 4 year old poplar canopy) with four replications in split-split plot design were evaluated. Results of the study revealed that yield and other parameters of flowering annuals were low in crops that were in association with poplar than in open environmental condition. Among the crops studied, Coreopsis tinctoria, Coreopsis lanceolata, Phlox drumondii and Gaillardia pulchelia showed better performance than the other crops in both conditions. The poplar growth parameters such as tree height, diameter at breast height, crown spread, crown height and tree volume/fresh weight showed better performance under agroforestry plantation than without inter-cultivation. Benefit-cost ratio of growing flowers for seed production ranged from 1.15 to 5.31 under three year old poplar canopy and 1.68 to 5.51 in open environment. The corresponding values were 1.12 to 5.17 and 1.40 to 5.37 for four year old poplar canopy and open environment. In comparison to traditionally grown wheat crop, flower annuals were found profitable under poplar canopy as well as in open environment.*

Key words: *Benefit-cost ratio, Poplar seed production, Wheat, Winter flower annuals.*

INTRODUCTION

The fast agricultural development in the Punjab region of India has deteriorated the agro-ecosystem through excessive use of natural resources. Heavy depletion of soil health, lowering of water table and high rate of environmental pollution are the matters of great concern for the future of the state (Aulakh, 2005; Bambi and Brar, 2009). Diversification in agriculture in general and a rice-wheat rotation in particular has strongly been advocated in irrigated agro-ecosystems to conserve the natural resources. Poplar (*Populus deltoides*) based agroforestry systems are one of the viable alternative land use systems to diversify the rice-wheat rotation, prevent further degradation and obtain biological production on a sustainable basis. This system has already been adopted on large scale by the farmers in Punjab and adjoining states with intercultivation of traditional seasonal crops (Gupta *et al.*, 2005, Chauhan and Mangat, 2006). This system provides various products, which contribute to commercial and subsistence agricultural productivity as well as security to farm family livelihood. Additionally poplar based system holds potential for carbon sequestration as a means of converting low-biomass land use to tree based carbon rich systems (Chauhan *et al.*,

[*] To whom correspondence should be addressed: chauhanpau@rediffmail.com
[1] Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, India
[2] Department of Floriculture and Landscaping, Punjab Agricultural University, Ludhiana, India

2009). Poplar is among the world's fast growing industrial softwood species. Their deciduous nature and slender crown permits the intercultivation of a variety of seasonal and annual crops. However, poplar being sensitive to water logging, can check the traditional vicious cycle of rice-wheat systems in the region.

In the context of the global economy, farmers have to look for markets and shift their mindset from traditional to commercial agriculture. Often there is mismatch between the demand and the production. Farmers, for market security, often grow the crops which have the minimum support price fixed by the government rather than taking marketing risks for their produce/new options. Flower seed production seems one of the viable options to explore with great export potential and the north Indian climatic conditions are favorable for their cultivation (Chawla, 2004 and Singh *et al.,* 2009). The fluctuating market prices of poplar also demand commercial intercropping. Preliminary studies revealed that flower seed production can provide more income and has great future prospects in global markets (Chawla, 2004). The state of Punjab is highly suitable for flower seed production. The winter season in the region matches with the summer season climate of European countries, and therefore, most of crops suitable for those countries can successfully be grown in Punjab during winter months. Farmers have already entered into flower seed production and have reported 2.5 to 3 times more profit than traditionally grown wheat crops (Singh *et al,* 2009). Approximately 400 ha area in the state has been put under flower seed production. However, the prevailing high temperature for few species like *Gaillardia pulchelia, Dianthus barbatus, Calendula officinalis, Gamolepis elegans, Phlox drumondii, Verbena hybrida, Coreopsis lanceolata, Coreopsis tinctoria, Chrysanthemum multicaul, Petunia hybrida, Dimorphotheca aurantiaca and Helichrysum bracteatum* is not conducive and they require partial shade for proper seed production. Such species can be evaluated for seed production potential under tree canopy and an effort was made to evaluate winter flower annuals for seed production under poplar based canopies to test the hypothesis that flower seed production under a poplar canopy is remunerative than traditionally grown wheat crops.

MATERIALS AND METHODS

The study was carried out at the experimental area of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana, India during the year 2007 - 08 and 2008 - 09. The research site is situated at 247 m above the mean sea level and lies between 30^o - 54' N latitude and 75^o - 61'E longitude, which represent the central agroclimatic zone of the state. The climate is subtropical to tropical with a long dry season from late September to early June and a wet season from July to early September. The region receives maximum rainfall of about 700 mm during July-September and a few occasional showers during winter. During this period, temperature fluctuates around 29.9^0C. The experiments were conducted in a split-split plot design [main plot: age of poplar trees; sub plot: conditions of cultivation (under poplar canopy and open condition); sub-sub plot: flowering annuals] with a plot size of 2 x 4 m in four replications of 4 x 4 m tree spacing. Twelve winter flowering annuals (*Gaillardia pulchelia, Dianthus barbatus, Calendula officinalis, Gamolepis elegans, Phlox drumondii, Verbena hybrida, Coreopsis lanceolata, C. tinctoria, Chrysanthemum multicaul, Petunia hybrida, Dimorphotheca aurantiaca* and *Helichrysum bracteatum*) were raised under poplar canopy (3 and 4 year old) and in the open. The soil of the experiment site was loamy with pH of 7.5, available N= 202.80 kg/ha, P=24.52 kg/ha and K=158.10 kg/ha at the start of the experiment.

Crop parameters

The height of eight randomly selected flower plants from each plot was recorded in centimetres from ground level to tip of plant. Plant spread and flower size was taken as the average width of the selected plants/flowers from end to end point. Number of flowers in each plant was counted and per plant flower weight was measured. Flower duration was also recorded as the period during which flower bud opened to withering of petals. Seed yield of each plot was recorded and finally yield was extrapolated on a hectare basis.

A wheat crop was sown in a normal flat bed under poplar and as a control in the open. Yield and yield contributing parameters were recorded from randomly selected quadrates of 1 x 1m. The average grain yield of each quadrate was extrapolated to obtain per hectare value in quintals for economic comparison with flowering annuals.

Tree parameters

Height of nine trees /replication was measured in metres from ground level to the tip of the main shoot. The diameter at breast height (DBH) was measured in centimetres with digital caliper at 1.37 m above the ground level. The measurements of DBH were taken in two different directions perpendicular to each other and average DBH was calculated. The crown spread was measured in metres using measuring tape from the tree trunk in east-west and north-south directions and holding two poles touching tip of the opposite sides of the tree. The distance between these two directions was measured with the help of measuring tape and average was calculated. Height of crown was measured in metres from ground level to lowest shoot of the trees with the help of a graduated measuring rod. The tree volume (m^3) and fresh biomass (kg/tree) were estimated through the regression equations developed for the prevailing conditions by Sharma *et al.* (2007) and Dhanda and Verma (2001), respectively.

Statistical analysis

Data were analyzed by using technique of analysis of split-split plot design with four replications in accordance with the procedure outlined by Gomez and Gomez (1984) using CPCS-1 software developed by the Department of Mathematics and Statistics, PAU Ludhiana, India. Significant differences among the treatment means (flowering crops, conditions of growing, tree age and their interactions) for yield and yield contributing parameters were tested at the 5% level of significance.

RESULTS AND DISCUSSION

Winter flowering annuals

An appraisal of the data presented in Table 1 revealed non-significant effect in plant height, plant spread, number of flowers per plant, flower size, fresh flower weight, seed yield per plant and seed yield (quintal/ha) during both years. The response of crops during both years for growth and yield under tree canopy and open condition was significant. Crops differed significantly with higher values in open than under a poplar canopy. The interaction effect of different factors in different parameters was found to be significant but not discussed due to their complex nature. However, response of crops during both the years followed the same pattern though values were lower under the 4th year old plantation.

Flowering duration was comparatively longer under the poplar canopy than in the open (Table 2). Flowering was extended in all the crops mainly due to negative interaction of trees on crops for light, moisture and change in microclimate under the trees (Table 3). The longer duration period under poplar canopy was due to continuous shade, which had adverse effects on vegetative growth i.e. plant height, plant spread, flower size, etc. Delaying physiological maturity under low light, low temperature and higher humidity increased seed filling duration. Variation in flowering duration among different crops is due to different periods of flowering and its relation to the phenology of poplar trees. Flowers remained open for the longest duration in *Gaillardia pulchelia* than in other crop, whereas, *Verbena hybrida* lasted for a minimum number of days. Hadi *et al.* (2006) and Nasurullahzadeh *et al.* (2007) reported delayed maturity under low light including increased flowering period and grain filling duration. The seed yield was significantly higher in the open than under poplar canopy (Table 1). Highest seed yield was observed in *Coreopsis tinctoria* and low in *Helichrysum bracteatum*. The variable conditions of crop growing and different crops exhibited significant variation for per plant seed yield. The differences in seed yield irrespective of crops and growing conditions during both years were marginal and non-significant, which may be due to non-significant differences in tree crown spread during both the years and intrinsic potential of the crops.

Table 2. Flowering duration under poplar canopy*

Crop	2007-08		2008-09	
	Control	Under poplar canopy	Control	Under poplar canopy
Verbena hybrida	25th February- 7th April (79)	4th March-20th April (86)	4th March - 15th May (86)	8th March-25thMay (90)
Gamolepis elegans	10th January- 15thMarch (33)	15th January- 1stApril (38)	26th January - 27thMarch (49)	2nd February-12thApril (25)
Petunia hybrida	5th March- 24thMay (113)	3rd March- 30thMay (85)	3rd March - 26thMay (85)	10th March-30thMay (92)
Dimorphotheca aurantiaca	1st March- 20thApril (83)	7 March- 30thApril (89)	6th March - 25thApril (88)	9th March-30thApril (91)
Chrysanthemum multicaul	10th February- 2thApril (64)	28th February- 20thApril (82)	11th February- 6thApril (65)	15th February- 15thApril (66)
Phlox drumondii	25th February- 28thApril (79)	10th March- 15thMay (84)	10th March - 28thMay (92)	11th March-29thMay (93)
Gaillardia pulchelia	5th May - 15thJuly (148)	8th May- 27thJuly (151)	1st May- 3rdAugust (144)	10th May-22ndAugust (153)
Helichrysum bracteatum	1th March- 15thMay (83)	6th March- 25thMay (88)	5th March - 16thMay (84)	10th March-29thMay (153)
Calendula officinalis	15th February- 6thApril (69)	18th February- 15thApril (72)	15th February to 1stApril (69)	20th February- 21stApril (74)
Coreopsis tinctoria	10th April- 25thJune (123)	13th April- 10thJuly (126)	14th April to 30thJune (127)	16th April-15thJuly (129)
Coreopsis lanceolata	11th April- 25thJune (124)	14th April- 16thJuly (127)	14th April to 13thJune (127)	20th April-22ndJuly (133)
Dianthus barbatus	25th January- 28thMarch (48)	30th January- 18thApril (53)	23rd January- 25thMarch (46)	28th January-20thApril (51)

*Number of days to flowering in parentheses

The marginal decrease in seed yield under the fourth year plantation than in the third year plantation was mainly due to the micro-climatic changes i.e light, temperature, humidity caused by increase of tree canopy with age (Table 3). More seed yield was recorded in control due to better growth of plants because of less competition for light, moisture and nutrient leading to more number of branches, flower and ultimately production of more number of heads per plant, which resulted in increased seed yield. The seed yield decreased gradually with reducing light or increasing shade.

The tree-crop interface leads to complex interactions (ecological as well as economical) among biophysical components and their interaction contributes to the success of the tree-crop interface. The meteorological parameters (air/soil temperature, humidity and light intensity) revealed lower values for light and temperature under canopy, while relative humidity was higher, which are critical to the physiological processes responsible for growth and development of understorey crops (Table 3).

Table 3. Mean monthly meteorological data of the experimental site (2009)

Parameters / Months		Air temperature (^oC)		Relative humidity (%)		Soil temperature (^oC)		Light intensity (100 Lux)	
		Morning	Afternoon	Morning	Afternoon	Morning	Afternoon	Morning	Afternoon
January	E_1	20.59	15.50	46.00	95.00	*	*	363.25	100.0
	E_2	19.85	14.50	46.29	100.0	*	*	268.25	80.00
February	E_1	24.13	30.40	47.01	44.05	33.50	10.00	645.7	240.0
	E_2	23.33	26.60	45.74	41.40	25.50	7.80	638.0	216.0
March	E_1	27.59	28.53	46.74	41.40	30.75	16.90	510.11	352.0
	E_2	29.35	23.68	44.92	40.95	26.50	14.50	468.50	308.57
April	E_1	32.26	31.63	37.98	35.07	38.00	22.00	290.0	862.88
	E_2	33.02	34.83	34.18	37.87	35.25	20.0	152.8	119.0
May	E_1	34.11	41.58	49.39	40.80	33.50	28.20	1106.2	544.0
	E_2	33.69	35.20	50.5	36.35	30.00	28.00	137.44	85.00
June	E_1	39.40	37.37	50.67	57.07	*	*	*	*
	E_2	36.47	34.80	52.17	56.33	*	*	*	*
July	E_1	35.15	33.10	75.90	79.10	*	*	*	*
	E_2	32.25	30.90	79.30	82.40	*	*	*	*

E_1- Control; E_2- Under poplar canopy;
*- Not recorded

Tree parameters

The data on growth parameters of three and four year old poplar tree are presented in Table 4. Trees showed significant differences for growth and yield parameters between growing environments. The performance of trees in agroforestry plantations was significantly more than in the pure plantation. The pooled mean values revealed approximately 15 and 12.52 % increase due to inter-cultivation than in the uncultivated plantation in tree height and diameter at breast height, respectively. However, non-significant differences in crown spread were noticed during both the years and also within the environments. The non-significant differences in crown spread are due to the pruning exerted in the trees required for knot free clean boles and more light for inter-cultivated crops. Poplar trees in the present study were pruned annually thus exhibiting less variation. The leaf area index values recorded during the crop season also exhibited a non-significant variation. Values under agroforestry ranged from 0.063 - 0.311 and in pure plantation 0.048 - 0.303. The tree volume and biomass followed the trend of tree height/diameter and significant differences in both the parameters were recorded over the year of growth and the environment of cultivation. The poplar trees showed better growth in the inter-cultivation than uncultivated conditions (Table 4). The higher production of poplar when cultivated with seasonal crops may be due to the benefits drawn by the poplar by the various agricultural inputs. Singh and Sharma (2007) also recorded 17.2 and 15.6 % increases in tree height and diameter in fodder-wheat intercropping. The higher growth is also due to ideal environmental conditions i.e., humidity, temperature, etc. under intercultivated crops.

Table 4. Growth performance of *Populus deltoides* under farm forestry

Parameters / Conditions	2008			2009			CD at 5%
	E_1	E_2	Mean	E_1	E_2	Mean	
Tree height (m)	8.38	7.40	7.89	15.67	13.53	14.60	Year :1.04 Condition :1.24 Year x condition:NS
DBH (cm)	8.57	7.19	7.88	16.06	14.70	15.38	Year :1.16 Condition:0.82 Year x condition: NS
Crown spread (m)	3.23	3.20	3.21	4.07	3.79	3.93	Year :NS Condition :NS Year x condition: NS
Crown height (m)	4.15	3.85	4.00	9.09	7.72	8.40	Year :1.45 Condition :NS Year x condition: NS
Volume (cum)	0.06	0.038	0.049	0.40	0.292	0.35	Year :0.082 Condition :NS Year x condition: NS
Fresh timber weight (kg/tree)	18.68	15.67	17.18	80.08	73.30	76.69	Year :7.38 Condition :3.21 Year x condition: NS
Fresh total tree biomass (kg)	53.39	44.79	49.09	178.35	163.27	170.82	Year :36.42 Condition :8.09 Year x condition: NS

E_1-Agroforestry Plantation; E_2-Pure plantation

Economic analysis

Benefit cost ratio of growing flowers for seed production ranged from 1.53 (*Helichrysum bracteatum)* to 5.59 (*Petunia hybrida)* under open conditions and 1.15 (*Helichrysum bracteatum)* to 5.31 (*Petunia hybrida)* under three year old poplar canopy. However, under four year old poplar, the benefit: cost ratio ranged from 1.12 *(Helichrysum bacteatum)* to 5.17 (*Petunia hybrida)* and in open condition, 1.40 (*Helichrysum bacteatum)* to 5.37 *(Gaillardia pulchelia). Verbena hybrida*, *Gamolepis elegans, Petunia hybrida, Phlox drumondii, Coreopsis spp.* and *Dianthus barbatus* were found to be more profitable than the other flower crops (Table 5). Benefit: cost ratio of wheat cultivation in control (1.25) and under poplar canopy (0.57) was comparatively less than the flower seed production. All the flower crops were found to be quite remunerative than the traditionally grown wheat crop in open as well as under poplar canopy. The results of present study agree with findings of Kumar *et al.* (2004), Singh and Dhaliwal (2005), Chaudhary *et al.* (2007) and Dwivedi *et al.* (2007). Higher output of flower seeds than a wheat crop in open conditions has been reported by Singh *et al.* (2009). Flowers for seed production are relatively remunerative enterprises as compared to the predominant rabi crop i.e., wheat. However, the higher earnings depend on skills, management practices, selection flower crop and marketing strategy.

Table 5. Comparative economics of flowers meant for seed production and general competing wheat crop*.

Crop	Yield (q/ha)		Gross returns (Rs)		Total variable cost (Rs)		Return over variable cost		Benefit cost ratio	
	A.F	Open	A.F	Open	A.F.	Open	A.F	Open	A.F	Open
Verbena	2.68	2.43	80,400	72,900	16162.5	16762.5	64237.5	56137.5	3.97	3.35
Hybrida	(2.05)	(2.35)	(61500)	(70500)	(16162.5)	(16762.5)	(45337.5)	(53737.5)	(2.81)	(3.21)
Gamolepis	2.38	2.75	59,500	68,750	15270	15500	44230	53250	2.90	3.44
elegans	(2.33)	(2.68)	(58250)	(67000)	(15270)	(15500)	(42980)	(51500)	(2.81)	(3.32)
Petunia	1.38	1.50	110,400	120,000	17500	18202	92900	101797.5	5.31	5.59
Hybrida	(1.35)	(1.43)	(108000)	(114400)	(17500)	(18202)	(90500)	(96197.5)	(5.17)	(5.28)
Dimorphotheca	1.50	1.75	45,000	52,500	16162.5	16762	28837.5	35737.5	1.78	2.13
aurantiaca	(1.43)	(1.70)	(42900)	(51000)	(16162.5)	(16762)	(26737.5)	(34237.5)	(1.65)	(2.04)
Chrysanthemum	1.30	1.75	39,000	52,500	16162.5	116762.5	22837.5	35737.5	1.41	2.13
multicaul	(1.23)	(1.70)	(36900)	(51000)	(16162.5)	(116762.)	(20737.5)	(34237.5)	(1.28)	(2.04)
Phlox	1.60	1.80	56,000	63,000	16420	16762.5	39580	46237.5	2.41	2.76
drumondii	(1.58)	(1.93)	(55300)	(67550)	(16420)	(16762.5)	(38880)	(50787.5)	(2.37)	(3.03)
Gaillardia	4.55	5.03	113,750	125,750	19037.5	19817.5	94712.5	105932.5	4.98	5.35
pulchelia	(4.55)	(5.05)	(113750)	(126250)	(19037.5)	(19817.5)	(94712.5)	(106432.5)	(4.98)	(5.37)
Helichrysum	1.25	1.53	37,500	45,900	17412.5	18112.5	20087.5	27787.5	1.15	1.53
bracteatum	(1.23)	(1.45)	(36900)	(43500)	(17412.5)	(18112.5)	(19487.5)	(25387.5)	(1.12)	(1.40)
Calendula	2.10	2.28	42,000	45,600	16162.5	16762.5	25837.5	28837.5	1.60	1.72
officinalis	(2.05)	(2.23)	(41000)	(44600)	(16162.5)	(16762.5)	(24837.5)	(27937.5)	(1.54)	(1.66)
Coreopsis	6.03	6.38	96,480	102,080	19037.5	19557.5	77442.5	82522.5	4.07	4.22
tinctoria	(5.98)	(6.33)	(95680)	(101280)	(19037.5)	(19557.5)	(76642.5)	(81722.5)	(4.03)	(4.18)
Coreopsis	4.83	5.00	77,280	80,000	19037.5	19557.5	58242.5	60442.5	3.06	3.09
lanceolata	(4.83)	(5.05)	(77280)	(80800)	(19037.5)	(19557.5)	(58242.5)	(61242.5)	(3.06)	(3.13)
Dianthus	1.88	2.20	56,400	66,000	16162.5	16505	40237.5	49495	2.49	3.00
barbatus	(1.85)	(2.18)	(55500)	(65400)	(16162.5)	(16505)	(39337.5)	(48895)	(2.43)	(2.96)
Triticum	27.17	42.92	33485	53077	21387.5	23625	12097	29452	0.57	1.25
asetivum	(33.73)	(45.3)	(42668)	(57304)	(21387.5)	(23625)	21281	(33679)	(0.99)	(1.42)
A:Main product	40.0	64.38								
(grains)	(50.60)	(67.9).								
B:By product										
(straw)										

*Figures in parentheses represent data recorded during 2008-09, whereas as outside parentheses is recorded during 2007-08.

Crop enterprise budgets are subject to prevailing weather conditions of 2007-09.

All input/ technologies are used as per the PAU recommendations.

Inputs are evaluated at the prevailing market prices. Seedling cost is not included in input cost.

Fixed costs such as land rent, depreciation, poplar trees, etc. are not included.

Benefit has been calculated on the prevailing flowering annuals seed rates. The benefit: cost ratio for a particular crop and inter-crop comparisons should therefore be viewed cautiously

1 US$ = Rs.45.5

CONCLUSION

Seed production of flowering annuals under poplar canopy was less than open condition, however, the poplar based agroforestry with flowering annuals offer excellent opportunities for farm diversification and more income than traditional crops in open as well as under poplar canopies.

REFERENCES

Aulakh, K. S. (2005). Crop diversification is a necessity: Paddy a drain on Punjab water resources. The Tribune, Chandigarh, India February 25.

Bambi, D. K., and Brar, J. S. (2009). A 25 year record of carbon sequestration and soil properties in intensive agriculture. Agron. Sustain. Dev. 29, 257- 265.

Chaudhry, A. K., Khan, G. S. and Ahmad, I. (2007). Comparison of economic returns from poplar-wheat, fodder maize intercropping to monoculture. Pak. J. Agri. Sci. 44(3), 459-466.

Chauhan, S. K., Sharma, S.K., Beri, V., Ritu, Yadav, S. and Gupta, N. (2010). Yield and carbon sequestration potential of wheat (*Triticum aestivum*)-poplar (*Populus deltoides*) based agri-silvicultural system. Ind. J. Agric. Sci. 80(2), 129-135.

Chauhan, S.K. and Mangat, P.S. ((2006). Poplar-based agroforestry is ideal for Punjab. APA News Asia-Pacific Agroforestry Newsletter. 28, 7-8.

Chawla, K. S. (2004). Big boost to floriculture. The Tribune, Chandigarh, India. January 15.

Dhanda, R. S. and Verma, R. K. (2001). Timber volume and weight tables of farm grown poplar (*Populus deltoides* Bartr. Ex Marsh.) in Punjab. Ind. Forestry 127(1), 115-130.

Dwivedi, R. P., Kareemulla, K., Singh, R., Rizvi, R.H. and Chauhan, J. (2007). Socio-economic analysis of agroforestry system in western Uttar Pradesh. Ind. Res. J. Ext. Edu. 7(2&3),18-22.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd ed. John Willey and Sons, New York, NY. pp. 680.

Gupta, D.C., Zomer, R.J., Bossio, D.A. (2005). Poplar agroforestry in India: Trends and impacts. IWMI project report. Colombo, Sri Lanka. International Water Management Institute, pp.57.

Hadi, H., Ghassemi-Golezani,K. Kholi, R.F., Valizadeh, M. and Shakiba, M.R. (2006). Responses of common bean (*Phaseolus vulgaris* L.) to different levels of shade. J. Agron. 5(4), 595-599.

Kumar, R., Gupta, P. K. and Gulati, A. (2004). Viable agroforestry models and their economics in Yamunanagar districts of Haryana and Haridwar of Uttranchal. Ind. J. Forestry 130(2), 131-148.

Nasurullahzadeh, S., Ghassemi-Golezani, K., Javanshir,A., Valizade, M. and Shakiba, MR. (2007). Effect of shade stress on ground cover and grain yield of faba bean (*Vicia faba* L.). J. Food Agric. and Envt. 5(1), 337-340.

Sharma, S.C., Dogra, A.S., Upadhyay, A. and Chahal, A.S. (2007). Carbon stock and productivity assessment of *Populus deltoides* Bartr ex Marsh in Punjab. Ind. J. Forestry 133(1), 8-16.

Singh, B. and Shama, K. N. (2007). Tree growth and nutrient status of soil in a poplar (*Populus deltoides* Bartr.) based agroforestry system in Punjab, India. Agroforestry Systems 70, 113-124.

Singh, R., Dhaliwal, H. S. and Joshi, A. S. (2009). Contract farming of floriculture in Punjab-problems and prospects. Floric. Today 13(11), 32-37.

Singh, S. and Dhaliwal, H. S. (2005). An economic analysis of poplar based agroforestry system in Punjab, Ind. Ind. J. Forestry 28 (4), 381-388.