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Flower seed production for remunerative returns under poplar based agroforestry system

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ABSTRACT: Low returns from traditional crops, over exploitation of natural resources and the ever-increasing demand for fuel, fodder and timber are the main reasons that compel farmers to integrate trees into the farmland. Poplar tree based agroforestry is emerging as one of the diversification options for the farmers in irrigated agro-ecosystem in north western states of India because a highly lucrative market for its timber is readily available. To make the poplar (*Populus deltoides*) based agroforestry systems economically more profitable, twelve winter flower annuals were evaluated in comparison to traditional wheat crop. Results of the study revealed that yield and other parameters of flowering annuals and wheat crop were comparatively low in association with poplar than in open conditions. Flowering annuals like *Coreopsis tinctoria, Coreopsis lanceolata, Phlox drumondii* and *Gaillardia pulchelia* showed better performance than the other flowering annual crops in both the conditions. Study showed that flower seed production of these species under poplar canopy is quite remunerative than growing traditional wheat crop. The tree growth performance was also found better under agroforestry plantation than without intercropping.

Key words: Economics, flowering annuals, intercropping, poplar, seed yield and wheat

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1. INTRODUCTION

Agriculture is the dominant land use in Punjab state (India) with over 84% of land under intensive cultivation. Diversification in agriculture in general and rice-wheat rotation in particular has strongly been advocated in irrigated agro-ecosystem to conserve the natural resources. The traditional crop rotation is also loosing profitability but still followed due to assured minimum support price (MSP). Agroforestry, one of the important alternative for diversification is gaining importance for higher productivity and economic gains. Agroforestry is a dynamic, ecologically sound, natural resource conserving practice rather than resource depleting system. However, farmers are adopting the practice because of enhanced market demands of plywood, paper and furniture units for farm grown timber. Punjab and adjoining states are expanding base for the wood based business and major brands in the country (Century, Greenply, Venus, kitply, Kamdhenu, etc.) have started their units in the region. With the upswinging of wood prices in recent years and friendly onfarm timber trade policies, farmers are now not much attracted for MSP for cereals but even shifted from boundary plantation to block timber tree plantations. Income from agroforestry produce has far exceeded from traditional crops thus increasing enthusiasm among farmers to adopt agroforestry interventions.

Poplar based agroforestry system is one of the viable alternative land use system to prevent further degradation and obtain biological production on sustainable basis (Rani *et al.,* 2011). Due to its major contribution to commercial and subsistence agriculture productivity Punjab's farmers adopted this system on large scale. Intercropping of poplar with compatible seasonal crops is essential not only for generating continuous supplementary income but also for creating on-farm employment. There is loss of agricultural production arising from the transfer of land to tree plantations but poplar being deciduous in nature has little affect on the winter crops and normally wheat is grown during winter season. There is extensive loss of agricultural production during summer season due to tree shade, and this as a result can reduce area under rice cultivation through adoption of poplar based agroforestry system.

The flexibility in intercropping has even generated interest among small and marginal farmers into low volume high value crop based agroforestry. The North Indian climatic conditions particularly winter seems one of the congenial environment for flower seed production (Singh *et al.,* 2009). The fluctuating market prices of poplar also demand commercial intercropping for economic security. In future global market flower seed production has higher potential than traditional crop rotation as former provides more income. Winter season of Punjab provides all the favorable climatic conditions for optimum flower seed production which matches the climatic conditions of summer in European countries and farmers have reported 2.5 to 3 times more profit than wheat cultivation. Approximately 1000 acre area in the state has been under flower seed production (Chawla, 2004; Dhanda *et al.,* 2007) and increasing steadily but their intercropping under agroforestry system requires interaction and economic evaluation.

Cultivation of flowers for seed production under tree canopy can be of great significance if suitable crops are selected. There are few species (*Gaillardia pulchella, Dianthus barbatus, Calendula officinalis, Gamolepis elegans, Phlox drumondii, Verbena hybrida, Coreopsis lanceolata, Coreopsis tinctoria, Chrysanthemum multicaul, Petunia hybrida, Dimorphotheca aurantiaca, Calendula officinalis, Alyssum maritimum, Gazania splendens, Helichrysum bracteatum, etc.*) for which the prevailing high temperature is not conducive and they require partial shade for proper seed production, maturity and viability. Such species can be evaluated for seed production potential under agroforestry systems.

2. MATERIALS AND METHODS

The experiment was conducted for three years at the experimental area of the Department of Forestry and Natural Resources, College of Agriculture, Punjab Agricultural University, Ludhiana (30°-54' latitude and 75°-61'longitude, 247 m above sea level), which represent the central agro-climatic zone of the state. The climate in this region is subtropical to tropical with a long dry season from late September to early June and a wet season from July to early September with hot desiccating winds in summer (May-June) and severe cold in winter with occasional ground frost (December-January). Mean annual precipitation of the experimental site is 700 mm, most of it falling from July to September and temperature fluctuates around 29.9°C during this month. The soil of the experimental site was loamy with pH 7.5, available N=202.80 kg ha^{-1}, P=24.52 kg ha^{-1} and K=158.10 kg ha^{-1}. 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 i.e., *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 for three years under poplar canopy (3, 4 and 5 year old) and in the open condition as control for comparison. Before selection of annual crops for study, preliminary experiment was conducted under two year old poplar plantation and based on the performance, these flowering annuals were selected. Initial two year's results have been reported earlier (Rani *et al.,* 2011) but for year-wise comparison detailed data on flower parameters is included in this paper.

Crop parameters

From each plot the height of eight randomly selected flower plants was recorded in centimeters from ground level to tip of plant. Flower weight per plant and number of flowers in each plant was counted simultaneously plant spread and flower size was also taken from the selected plants.

Seed yield of each plot was recorded and finally yield was extrapolated on a hectare basis in quintals (1 ton = 10 quintals). The adoption potential of crop system depends upon the economics of the landuse system, therefore, benefit cost ratio of cultivating flowering annuals for seed production was estimated for growing them under poplar and in open condition for their suitability.

Tree parameters

Height of the trees was measured in meters (m) from ground level to the tip of the main shoot of the trees with the help of Indian made multimeter. Nine trees per replication were randomly selected for recording the growth data. *Populus deltoides* trees were measured for their diameter at breast height (cm) with the help of digital caliper, crown spread (m) by using measuring tape from the tree trunk in east-west and north-south directions and holding two poles straight touching tip of the opposite sides of the tree and crown height (m) with the help of graduated measuring rod from ground level to lowest shoot of the trees. The tree volume (m^3) and fresh biomass (kg $tree^{-1}$) was estimated by fitting the tree height and dbh values through the regression equations developed by Sharma *et al.* (2007).

Statistical analysis

Statistical analysis of data was performed as per the procedure explained by Gomez and Gomez (1984) and using CPCS-1 software developed by the Department of Mathematics and Statistics, PAU Ludhiana (India).

3. RESULTS AND DISCUSSION

Winter flowering annuals growth and yield

Exhaustive data on plant growth, flower and seed yield of flowering annuals were recorded for three years under poplar and for comparison in open condition. The data presented in Tables 1-3 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 (q ha^{-1}) during the three years of study. Though, the response of crops during all the three years for growth and seed yield under tree canopy and open condition was significantly different but trend of response remained the same. Crops differed significantly with higher values in open than under poplar canopy. The interaction effect of different factors in different parameters was found significant but not discussed due

Table 1. Plant height (cm) and plant spread (cm)* of winter flower annuals under poplar tree canopy and open condition

Crops	Poplar (3rd year)	Control	Yearly mean	Poplar (4th year)	Control	Yearly mean	Poplar (5th year)	Control	Yearly Mean	Pooled average		
										Poplar	Control	Pool mean
Verbena hybrid	29.50 (19.06)	29.44 (21.06)	29.47 (20.06)	21.50 (23.06)	18.94 (23.63)	20.22 (23.34)	29.00 (16.58)	32.00 (20.06)	30.50 (18.32)	26.67 (19.57)	26.79 (21.58)	26.73 (20.58)
Gamolepis elegans	27.63 (23.75)	21.69 (24.75)	24.66 (24.25)	20.94 (27.69)	21.00 (29.63)	20.97 (28.66)	30.17 (25.92)	25.30 (26.01)	27.74 (25.96)	26.25 (25.79)	22.66 (26.79)	24.46 (26.29)
Petunia Hybrid	64.94 (41.69)	63.19 (43.19)	64.07 (42.44)	65.69 (42.44)	60.25 (46.50)	62.97 (44.47)	65.00 (26.67)	66.00 (40.58)	65.50 (33.625)	65.21 (36.93)	63.15 (43.42)	64.18 (40.18)
Dimorphotheca aurantiaca	19.94 (27.38)	21.88 (36.19)	20.91 (31.78)	21.44 (27.38)	21.63 (34.88)	21.54 31.13	20.17 (27.50)	24.00 (30.33)	22.09 (28.915)	20.52 (27.42)	22.50 (33.80)	21.51 (30.61)
Chrysanthemum multicaul	22.19 (28.88)	22.25 (36.13)	22.22 (32.50)	23.47 (31.81)	19.75 (35.88)	21.61 33.84	23.00 (30.00)	24.00 (37.00)	23.50 (33.50)	22.89 (30.23)	22.00 (36.34)	22.44 (33.28)
Phlox drumondii	25.25 (28.63)	48.44 (30.69)	36.85 (29.66)	26.50 (21.69)	29.81 (26.94)	28.16 24.31	26.00 (22.00)	47.67 (29.67)	36.84 (25.835)	25.92 (24.11)	41.97 (29.10)	33.95 (26.61)
Gaillardia pulchella	80.38 (43.19)	81.31 (47.25)	80.85 (45.22)	81.00 (49.69)	75.38 (53.06)	78.19 51.38	77.11 (47.01)	77.33 (49.33)	77.22 (48.17)	79.50 (46.63)	78.01 (49.88)	78.75 (48.26)
Helichrysum bracteatum	74.19 (34.38)	73.38 (36.44)	73.79 (35.41)	74.56 (23.69)	66.31 (23.88)	70.44 23.78	70.00 (34.34)	75.00 (37.00)	72.50 (35.67)	72.92 (30.80)	71.56 (32.44)	72.24 (31.62)
Calendula officinalis	39.88 (32.81)	41.94 (34.69)	40.91 (33.75)	28.00 (26.75)	39.94 (32.13)	33.97 29.44)	40.4 (37.30)	46.00 (39.83)	43.20 (38.565)	36.09 (32.29)	42.63 (35.55)	39.36 (33.92)
Coreopsis tinctoria	76.31 (41.38)	76.13 (42.75)	76.22 (42.06)	84.38 (42.56)	115.44 (44.50)	99.91 43.53	75.33 (29.50)	77.00 (35.00)	76.17 (32.25)	78.67 (37.81)	89.52 (40.75)	84.10 (39.28)
Coreopsis lanceolata	76.50 (39.25)	73.06 (45.69)	74.78 (42.47)	73.69 (38.75)	79.13 (48.38)	76.41 43.56	76.84 (39.84)	80.17 (38.17)	78.51 (39.005)	75.68 (39.28)	77.45 (44.08)	76.58 (41.68)
Dianthus barbatus	33.81 (11.88)	46.31 (15.06)	40.06 (13.47)	35.38 (9.47)	58.56 (12.44)	46.97 10.95	35.34 (12.00)	35.34 (16.00)	40.17 (14.00)	34.84 (11.12)	49.96 (14.50)	42.40 (12.81)
Mean	47.54 (31.02)	49.92 (34.49)	48.73 (32.76)	46.38 (30.41)	50.51 (34.32)	48.45 32.37	47.36 (29.06)	47.36 (33.25)	49.49 (31.15)	47.09 (13.16)	50.68 (34.02)	48.89 (23.59)

CD at 5%					
Years	:	NS (NS)	Years x Conditions	:	NS (NS)
Environments	:	0.85 (1.31)	Years x Crops	:	2.86 (3.01)
Crops	:	1.34 (1.92)	Environments x Crops	:	2.86 (3.01)
			Years x Environments x Crops	:	5.88 (2.33)

*Plant spread in parentheses

Table 2. Number of flower/plant and flower size* (cm) of winter annuals under poplar tree canopy and open condition

Crops	Poplar (3rd year)	Control	Yearly mean	Poplar (4th year)	Control	Yearly mean	Poplar (5th year)	Control	Yearly mean	Pooled average		
										Poplar	Control	Pool mean
Verbena	84.25	94.00	89.13	106.69(	100.25	103.47	61.80	68.83	65.315	84.25	87.69	85.97
hybrida	(1.86)	(1.97)	(1.92)	1.77)	(1.76)	(1.77)	(1.88)	(1.99)	(1.94)	(3.13)	(3.06)	(3.10)
Gamolepis	60.50	62.75	61.63	57.75	62.5	60.125	55.84	63.67	59.755	58.03	62.97	60.50
elegans	(2.93)	(2.51)	(2.72)	(2.86)	(2.87)	(2.87)	(3.59)	(3.80)	(3.69)	(5.51)	(5.74)	(5.63)
Petunia	42.00	38.50	40.25	39.25	36.25	37.75	26.67	36.17	31.42	35.97	36.97	36.47
hybrida	(5.18)	(5.36)	(5.27)	(6.33)	(6.75)	(6.54)	(5.01)	(5.10)	(5.06)	(5.94)	(5.91)	(5.93)
Dimorphothec	28.25	30.25	29.25	29.00	30.25	29.625	29.84	39.00	34.42	29.03	33.17	31.10
a aurantiaca	(6.45)	(6.13)	(6.29)	(5.11)	(5.59)	(5.35)	(6.27)	(6.00)	(6.14)	(2.45)	(2.55)	(2.50)
Chrysanthem	62.75	64.50	63.63	69.31	70.50	69.905	50.75	58.00	54.38	60.94	64.33	62.64
um multicaul	(2.39)	(2.18)	(2.29)	(2.55)	(3.03)	(2.79)	(2.40)	(2.45)	(2.43)	(2.33)	(2.47)	(2.40)
Phlox	101.75	206.25	154.00	124.69	271.0	197.85	48.83	85.00	66.92	91.76	187.42	139.60
drumondii	(2.27)	(2.47)	(2.37)	(2.34)	(2.52)	(2.43)	(2.38)	(2.43)	(2.41)	(5.03)	(5.26)	(5.15)
Gaillardia	37.75	36.00	36.88	37.62	41.50	39.56	17.88	39.00	28.44	31.08	38.83	34.96
pulchella	(5.39)	(5.53)	(5.46)	(4.49)	(4.98)	(4.74)	(5.21)	(5.28)	(5.25)	(4.40)	(4.37)	(4.39)
Helichrysum	25.25	23.75	24.50	18.56	16.25	17.41	27.00	28.50	27.75	23.60	22.83	23.22
bracteatum	(4.48)	(4.36)	(4.42)	(4.45)	(4.25)	(4.35)	(4.26)	(4.50)	(4.38)	(5.47)	(4.91)	(5.19)
Calendula	21.00	21.5	21.25	20.75	21.75	21.25	34.25	44.33	39.29	25.33	29.19	27.26
officinalis	(5.34)	(4.64)	(4.99)	(5.50)	(5.00)	(5.25)	(5.57)	(5.10)	(5.34)	(5.38)	(4.90)	(5.14)
Coreopsis	110.00	134.5	122.25	94.50	111.25	102.88	44.00	99.50	71.75	82.83	115.08	98.96
tinctoria	(5.78)	(5.69)	(5.735)	(4.99)	(3.57)	(4.28)	(5.38)	(5.45)	(5.42)	(5.97)	(5.80)	(5.89)
Coreopsis	44.25	51.00	47.63	24.75	51.75	38.25	25.00	50.84	37.92	31.33	51.01	41.17
lanceolata	(5.98)	(5.69)	(5.835)	(5.73)	(5.51)	(5.62)	(6.21)	(6.19)	(6.20)	(1.94)	(1.84)	(1.89)
Dianthus	51.25	52.00	51.63	45.62	49.25	47.44	45.55	58.67	52.11	47.47	53.31	50.39
barbatus	(1.86)	(1.62)	(1.74)	(2.00)	(1.90)	(1.95)	(1.95)	(2.00)	(1.98)	(4.12)	(4.06)	(4.09)
Mean	55.75	67.92	61.83	55.71	71.88	63.79	38.95	55.96	47.46	50.14	65.23	57.68
	(4.16)	(4.01)	(4.09)	(4.01)	(3.98)	(3.99)	(4.18)	(4.19)	(4.18)	(4.31)	(4.24)	(4.27)

CD at 5%
Years : NS (NS) — Years x Environments : 2.25 (NS)
Environments : 1.41 (NS) — Years x Crops : 7.81 (NS)
Crops : 4.46 (0.33) — Environments x Crops : 7.81 (NS)
Years x Environments x Crops : 16.11 (0.39)

*Flower size in parentheses

to their complex nature though clearly evident in tables. All the crops during the three years followed the same response pattern though values decreased with increase in age of poplar plantation. Flowering duration was extended in majority of the crops (mainly due to negative interaction of trees on crops for light, moisture and change in microclimate under the trees). The extended shade under poplar canopy had adverse effects on vegetative growth i.e. plant height, plant spread, flower size, etc. and delayed physiological maturity under low light, low temperature and higher humidity under canopy than open condition. Flowering duration of different crops varies due to phenology of poplar trees. *Gaillardia pulchelia* flowers remained open for longest duration than in other crop, whereas, *Verbena hybrida* lasted for a minimum number of days (Table 4). Delayed maturity under low light including increased flowering period and grain filling duration is reported by Hadi *et al.,* (2006) and Nasurullahzadeh *et al.,* (2007). Significantly higher seed yield was recorded in the open than under poplar canopy (Table 4). *Coreopsis tinctoria* recorded highest seed yield and low in *Petunia hybrida* and *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 the three 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. However, comparison of absolute seed yield among different species may not be appropriate because of their intrinsic genetic capacity and variable market prices, therefore economic analysis will apportion the actual reliable differences.

Economic analysis

The adoption of the farm intervention depends upon the ultimate economics and more importantly it should be

Table 3. Effect of poplar trees on fresh flower weight/plant (gm) of inter-cultivated winter flower annuals

Crops	Poplar (3^{rd} year)	Control	Yearly mean	Poplar (4^{th} year)	Control	Yearly mean	Poplar (5^{th} year)	Control	Yearly mean	Pooled average		
										Poplar	Control	Pool mean
Verbena hybrida	2.51	2.46	2.49	2.86	2.98	2.92	1.84	1.80	1.82	2.74	2.41	2.58
Gamolepis elegans	7.98	8.51	8.25	7.82	8.49	8.16	7.37	8.63	8.00	7.87	8.54	8.21
Petunia hybrida	12.23	10.76	11.50	9.62	11.71	10.67	7.77	10.11	8.94	10.49	10.86	10.68
Dimorphotheca aurantiaca	8.51	9.77	9.14	9.77	9.29	9.53	8.99	12.59	10.79	9.35	10.55	9.95
Chrysanthemum multicaul	33.41	33.37	33.39	35.84	36.69	36.27	27.02	30.01	28.52	35.03	33.36	34.19
Phlox drumondii	4.14	8.39	6.27	4.49	11.03	7.76	1.99	3.46	2.73	4.37	7.63	6.00
Gaillardia pulchella	61.59	62.90	62.25	65.75	73.96	69.86	29.17	68.14	48.66	64.36	68.33	66.35
Helichrysum bracteatum	58.75	36.89	47.82	35.70	38.78	37.24	62.82	44.27	53.55	43.38	39.98	41.68
Calendula officinalis	28.01	28.51	28.26	27.18	29.58	28.38	45.68	58.78	52.23	27.46	38.96	33.21
Coreopsis tinctoria	76.07	99.22	87.65	70.01	82.43	76.22	30.43	73.40	51.92	72.03	85.02	78.53
Coreopsis lanceolata	33.56	38.68	36.12	18.76	39.25	29.01	18.96	38.56	28.76	23.69	38.83	31.26
Dianthus barbatus	9.68	10.02	9.85	4.82	17.27	11.05	8.49	11.31	9.9	6.44	12.87	9.66
Mean	28.04	29.12	28.58	24.39	30.12	27.25	20.88	30.09	25.48	25.6	29.78	27.69
CD at 5%	Years	:	NS		Years x Environments				:	3.11		
	Environments	:	2.44		Years x Crops				:	6.49		
	Crops	:	3.98		Environments x Crops				:	6.49		
					Years x Environments x Crops				:	9.32		

more than the ongoing usual landuse system/crop rotation. Flower seed production intervention under poplar was found quite profitable than the wheat crop cultivation (sole as well as under poplar canopy). For growing flowers Benefit : cost ratio for seed production ranged from 1.72 (*Helichrysum bracteatum*) to 5.61 (*Gaillardia pulchelia*) under open conditions but 1.23 (*Chrysanthemum multicaul*) to 4.49 (*Petunia hybrida*) under poplar canopy. Similarly, Benefit: cost ratio of wheat cultivation recorded in control was comparatively higher (1.64) than under poplar canopy (0.66) but was comparatively less than the flower seed production (Table 5). All the flower crops were found more profitable than the traditionally grown wheat crop in open as well as under poplar canopy. However, on system basis the results are very different and when timber value is included, the benefit cost ratio shifts in favour of agroforestry in wheat as well. Kumar *et al*. (2004), Singh and Dhaliwal (2005), Chaudhary *et al*. (2007) and Dwivedi *et al.* (2007) have also reported that tree-crop interaction have adverse affect on crop productivity but the system productivity as well as profitability increases substantially. The reduced yield of the crops under the tree canopy, lowers down the profitability margin than sole crop cultivation but the overall profitability on system basis after tree harvesting is substantially high than traditional crop cultivation (Chauhan *et al*., 2010; Chandra, 2011), thus encourages the framers to invest in this sector and consider it a best performing low risk asset in near future (Sharma and Kumar, 2000a, b). The higher returns in poplar based intercropping are mainly due to higher productivity of poplar than without intercropping (Dhillon *et al*., 2001; Chauhan and Mangat, 2006; Bangarwa and Wuehlisch, 2009). Poplar has played a significant role in enhancing the income of the farmers and average economic returns per hectare of poplar based agroforestry is two to five times more than traditional crop rotation (Joshi, 1996; Dwivedi *et al*., 2007). Sensitivity analysis by Khullar *et al*., (2010) proved that the poplar based agroforestry practice is not risky for adoption.

a) Crop enterprise budgets are subject to prevailing weather conditions of respective cultivation year.

Table 4. Seed yield (q acre^{-1})* and seed yield plant^{-1} (g)** of winter flower annuals under poplar trees and open condition

Crops	Poplar (3rd year)	Control	Yearly mean	Poplar (4th year)	Control	Yearly mean	Poplar (5th year)	Control	Yearly mean	Pooled average		
										Poplar	Control	Crop mean
Verbena hybrida	1.07 (2.40)	0.97 (2.18)	1.02 (2.29)	0.82 (1.86)	0.94 (2.13)	0.88 (1.99)	0.78 (1.76)	0.65 (1.46)	0.72 (1.61)	0.89 (2.01)	0.85 (1.92)	0.87 (1.97)
Gamolepis elegans	0.95 (2.14)	1.10 (2.48)	1.03 (2.31)	0.93 (2.10)	1.07 (2.40)	1.00 (2.25)	0.88 (1.98)	1.12 (2.52)	1.00 (2.25)	0.92 (2.07)	1.09 (2.47)	1.01 (2.27)
Petunia hybrida	0.55 (1.25)	0.60 (1.36)	0.58 (1.30)	0.54 (1.21)	0.57 (1.29)	0.56 (1.25)	0.35 (0.79)	0.57 (1.28)	0.46 (1.04)	0.48 (1.08)	0.58 (1.31)	0.53 (1.19)
Dimorphotheca aurantiaca	0.60 (1.35)	0.70 (1.58)	0.65 (1.47)	0.57 (1.28)	0.68 (1.53)	0.62 (1.40)	0.63 (1.42)	0.91 (2.04)	0.77 (1.73)	0.60 (1.35)	0.76 (1.72)	0.68 (1.54)
Chrysanthemum multicaul	0.52 (1.18)	0.70 (1.57)	0.61 (1.37)	0.51 (1.16)	0.68 (1.54)	0.60 (1.35)	0.42 (0.95)	0.63 (1.41)	0.53 (1.18)	0.48 (1.10)	0.67 (1.51)	0.57 (1.31)
Phlox drumondii	0.64 (1.44)	0.72 (1.61)	0.68 (1.53)	0.63 (1.42)	0.77 (1.72)	0.70 (1.57)	0.31 (0.69)	0.29 (0.66)	0.30 (0.68)	0.52 (1.18)	0.59 (1.33)	0.55 (1.26)
Gaillardia pulchella	1.82 (4.11)	2.01 (4.51)	1.91 (4.31)	1.82 (4.10)	2.02 (4.54)	1.92 (4.32)	0.86 (1.94)	2.17 (4.88)	1.52 (3.41)	1.50 (3.38)	2.07 (4.64)	1.78 (4.01)
Helichrysum bracteatum	0.50 (1.13)	0.61 (1.37)	0.56 (1.25)	0.49 (4.10)	0.58 (1.31)	0.54 (1.21)	0.66 (1.48)	0.73 (1.65)	0.69 (1.57)	0.55 (1.24)	0.64 (1.44)	0.59 (1.34)
Calendula officinalis	0.84 (1.88)	0.91 (2.04)	0.87 (1.96)	0.82 (1.11)	0.89 (2.00)	0.86 (1.93)	1.04 (2.33)	1.08 (2.42)	1.06 (2.38)	0.90 (2.02)	0.96 (2.15)	0.93 (2.09)
Coreopsis tinctoria	2.41 (5.42)	2.55 (5.75)	2.48 (5.59)	2.39 (1.85)	2.53 (5.69)	2.46 (5.54)	0.96 (2.17)	1.89 (4.25)	1.43 (3.21)	1.92 (4.33)	2.32 (5.23)	2.12 (4.78)
Coreopsis lanceolata	1.93 (4.36)	2.04 (4.60)	1.99 (4.48)	1.92 5.39 (4.32)	2.02 (4.54)	1.97 (4.43)	1.09 (2.46)	2.04 (4.59)	1.57 (3.53)	1.65 (3.71)	2.03 (4.58)	1.84 (4.15)
Dianthus barbatus	0.75 (1.69)	0.88 (1.99)	0.82 (1.84)	0.74 (1.67)	0.87 (1.95)	0.80 (1.81)	0.67 (1.50)	0.99 (2.24)	0.83 (1.87)	0.72 (1.62)	0.91 (2.06)	0.815 (1.84)
Mean	1.05 (2.36)	1.15 (2.59)	1.10 (2.47)	1.02 (2.29)	1.13 (2.55)	1.08 (2.42)	0.72 (1.62)	1.09 (2.45)	0.91 (2.04)	0.93 (2.09)	1.12 (2.53)	1.025 (2.31)
Triticum aestivum	79.0	91.3	85.1	69.99 ()	80.6	75.3	70.0	80.0	65.0	73.0	83.97	78.4
CD at 5%	Years : 0.12 (NS)				Years x Environments : NS (NS)							
	Environments : 0.22 (0.11)				Years x Crops : NS (NS)							
	Crops : 0.39 (0.61)				Environments x Crops : NS (NS)							
					Years x Environments x Crops : NS (NS)							

*1 acres = 0.4047ha **Seed yield plant^{-1} (g) in parentheses

b) Inputs are valued at the prevailing market prices. Seedling cost is not included in input cost (1USD=Rs.62).

c) Fixed costs such as land rent, depreciation, etc. are not included.

d) Benefit has been calculated on the prevailing flowering annuals seed rates.

Tree parameters

In Table 6 the data on growth parameters of third, fourth and fifth year old poplar trees are presented. Trees showed significant differences for growth and yield parameters between growing environments. The performance of trees with crop cultivation was significantly more than in the pure plantation. Non-significant differences in crown spread were noticed during different 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 insolation for inter-cultivated crops. In the present study poplar trees were pruned annually, thus exhibiting less variation in canopy. The leaf area index values also exhibited a non-significant variation which is recorded during the crop season. Over the year of growth and the environment of cultivation the tree volume and biomass followed the trend of tree height/diameter and significant differences in both the parameters were recorded. 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 including regular cultural practices, irrigation, fertilization, etc. Usually poplar is recommended with inter-cultivation of agricultural crops,

Table 5. Economics of flower seed production under fifth year of poplar growth and wheat crop*

Items	Yield (q acre^{-1})**	Gross returns (Rs)	Total variable cost (Rs)	Return over variable cost	Benefit : cost ratio
Verbena	0.89	26,700	6,465	20,235	3.13
Hybrid	(0.85)	(25,500)	(6,705)	(18,795)	(2.80)
Gamolepis elegans	0.92	23,000	6,108	16,892	2.77
	(1.09)	(27,250)	(6,200)	(21,050)	(3.39)
Petunia	0.48	38,400	7,000	31,400	4.49
Hybrid	(0.58)	(46,400)	(7,281)	(39,119)	(5.37)
Dimorphotheca	0.6	18,000	6,465	11,535	1.78
aurantiaca	(0.76)	(22,800)	(6,705)	(16,095)	(2.40)
Chrysanthemum	0.48	14,400	6,465	7,935	1.23
multicaul	(0.67)	(20,100)	(6705)	(13,395)	(1.99)
Phlox	0.52	18,200	6,568	11,632	1.77
drumondii	(0.59)	(20,650)	(6,705)	(13,945)	(2.08)
Gaillardia pulchelia	1.50	37,500	7,615	29,885	3.92
	(2.07)	(51,750)	(7,927)	(44,505)	(5.61)
Helichrysum bracteatum	0.55	16,500	6,965	9,535	1.37
	(0.64)	(19,200)	(7,245)	(12,495)	(1.72)
Calendula officinalis	0.90	18,000	6,465	11,535	1.78
	(0.96)	(19,200)	(6,705)	(12,495)	(1.86)
Coreopsis tinctoria	1.92	30,720	7,615	23,105	3.03
	(2.32)	(37,120)	(7,823)	(29,297)	(3.74)
Coreopsis lanceolata	1.65	26,400	7,615	18,785	2.47
	(2.03)	(32,480)	(7,823)	(24,657)	(3.15)
Dianthus barbatus	0.72	21,600	6,465	15,135	2.34
	(0.91)	(27,300)	(6,602)	(20,698)	(3.13)
Triticum aestivum	10.87	13,394	8,555	5,339	0.66
A, main product	(17.17)	(21,231)	(8,555)	(13,176)	(1.64)
B, by product	16.0				
	(26.0)				

* Control conditions (with poplar canopy) in parentheses ** 1 acres = 0.4047ha

therefore, information on growth/biomass and economic viability in pure plantation are very limited. However, Singh *et al.* (1988), Chaturvedi (1992), Chaudhry *et al.* (2003), Verma (2008) recorded better growth of poplar under agroforestry conditions. Singh and Sharma (2007) also reported 17.2 and 15.6 per cent increases in tree height and diameter in fodder-wheat intercropping. The higher growth is also due to ideal environmental conditions i.e., humidity, temperature. under inter-cultivated crops. Dickman and Stuart (1983) observed that poplar trees are benefited from the intensive site preparation and fertilization, required to grow agricultural crops and in turn provide some protection for seasonal crops. Trees grown without inter-cultivation could not receive proper tillage and manurial requirements thereby resulting in poor performance. Furthermore, trees planted in and around the edges of fields were regularly ploughed and planted with agricultural crops, hence develop vigorous roots, attain more height, diameter and timber. On-farm trees provide a range of ecosystem services and environmental benefits (Jose, 2009) but all the tree components also add to the economics of the system. The systems store a large proportion of carbon in tree biomass as well, which may be helpful for additional earnings for the farmers through carbon marketing. Chauhan and Chauhan (2009); Yadava (2010); Rizvi *et al.* (2010); Chauhan *et al.* (2010a,b;2011;2012); Sharma and Sharma (2011); Gera *et al.* (2011); Benbi *et al.* (2012); Kanime *et al.* (2013); Arora *et al.* (2014) estimated carbon sequestration potential of poplar based tree-crop interface and suggested great potential of poplar based intercropping systems in reducing the atmospheric CO_2 concentration compared to sole cropping systems. However, data is insufficient, and an understanding of plant/climate relationships is essentially required to guide the future policies for carbon funding.

4. CONCLUSION

Various yield and yield contributing parameters of flowering annuals depicted their low performance in association with poplar than under open condition. But, flower seed production of these species under poplar canopy was found quite remunerative and offer excellent

Table 6. *Populus deltoides* growth with and without crop cultivation

Parameters / Environments	Poplar tree age									CD at 5%
	3rd year			4th year			5th year			
	E_1	E_2	Mean	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	21.96	19.66	20.81	Year :1.21 Environment :1.43 Year x Environment: NS
DBH (cm)	8.57	7.19	7.88	16.06	14.70	15.38	19.55	18.15	18.85	Year :1.74 Environment:1.16 Year x Environment: NS
Crown spread (m)	3.23	3.20	3.21	4.07	3.79	3.93	4.69	4.33	4.51	Year :NS Environment :NS Year x Environment: NS
Crown height (m)	4.15	3.85	4.00	9.09	7.72	8.40	16.38	14.85	15.62	Year :1.28 Environment :NS Year x Environment: NS
Stem volume (cum)	0.06	0.038	0.049	0.40	0.292	0.35	0.805	0.676	0.739	Year :0.084 Environment :NS Year x Environment: NS
Timber fresh weight (kg/tree)	18.68	15.67	17.18	80.08	73.30	76.69	179.32	167.43	173.37	Year :9.17 Environment :7.18 Year x Environment: NS
Total tree fresh biomass (kg)	53.39	44.79	49.09	178.35	163.27	170.82	354.53	326.56	340.55	Year :23.12 Environment :9.22 Year x Environment: NS

E1 (Environment 1) -Poplar plantation with inter-cultivated crop E2 (Environment 2) - Poplar plantation without inter-cultivated crop

opportunities for farm diversification with higher income than growing traditional wheat crop. Flower seed demands are increasing in developed countries and farmers can benefit through modified microclimate under tree canopy to raise flower annuals for seed and explore the growing export market.

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