

Role of Poplars in Agroforestry Systems in India

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Abstract: There is increasing gap between demand and supply of forest products leading to great pressure on natural forests. To reduce this gap, there is need to expand the land under tree cover by way of plantations and other afforestation works. But the horizontal expansion of land under tree cover is not possible. In such situations agroforestry is one of the viable options to increase the area under tree cover. There are many sustainable agroforestry systems in vogue in many parts of the world. Poplar based agroforestry system in northern parts of our country is one among them having great role in the socio-economic life of people. Globally, 91 per cent of poplars grow in natural forests, 6 per cent in plantations and remaining 3 per cent in agroforestry systems. China (73%) and India (49%) are the major countries having higher planted area of poplars. In India the poplar based agroforestry systems are found in Jammu and Kashmir, Himachal Pradesh, U P, Punjab, Haryana, Sikkim and Arunachal Pradesh. The features of poplar useful for agroforestry include fast growth (20-25 m³/ha/yr), straight clean bole, deciduous nature, multiple uses, soil enriching property, its compatibility with agricultural crops and high economic returns. It is highly water use efficient perennial component having high CO₂ exchange rate. The poplars are commonly propagated by cuttings having dimensions of 22 cm length and 1-3 cm diameter.

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1. Introduction

Forest cover of India has been estimated to be 637293 km² of the total geographical area of the country. Out of this, 7.76 % forest cover is in the form of open forests and another 1.58% is scrub forests (FSI, 2000). According to National Forest Policy 1988, one-third (33.33%) of the land area should be under the forest cover for sound ecological balance. It means that we have to bring another 13.94% areas under forest cover and at the same time improve quality of the degraded forests. However the horizontal expansion of land under tree cover is not possible. In order to increase the tree cover and fulfill the requirements of the people and industries, social forestry programs should be launched. As the country has a net sown area of 46.84% , it is one of the most important potential areas for tree growing along with the agriculture crop (FSI, 2000). In order to attract farmers toward agroforestry, we should have viable agroforestry models which can provide attractive financial returns to the farmers (Chauhan, 2000). There are many sustainable agroforestry systems in vague in many parts of India and among them is poplar (*Populus deltoides*) based agroforestry system (Puri et al., 2001). Poplars are distributed throughout the North West Himalayas and are growing in Jammu and Kashmir, Himachal Pradesh, Utrakhand, Punjab, Haryana, Uttar Pradesh and even in Madhya Pradesh also. The general altitudinal range is from 1200-3000 metres. It grows

well on moist deep soils however conditions of water logging should not occur. The seeds are very low in viability and they loss their viability within 3 weeks. Germination capacity is up to 80% when you collect viable seeds.

2. Why Poplar based Agroforestry system?

The poplar based Agroforestry system has gained popularity because of the following reasons:

- They have features favourable for Agroforestry system
 - Ready marketability of the produce
 - Encouragement from the private firms
 - Huge demand in wood based industries
 - Use of poplars for Carbon sequestration
 - Use of poplars for Phytoremediation
 - Absorption of nitrate pollutants from farms
 - To mitigate salinity (Armitage, 1985)

3. Features of poplars suitable for Agroforestry

- Fast growth – 20-25m³/ha/yr (Singh et al., 2001)
- Straight clean bole
- Leaflessness during winter
- Multiple uses-Pulpwood, packing cases, poles, timber, etc.
- Compatibility with agricultural crops
- High economic returns – Rs 88,749/acre @12 percent interest in seven years (Dillon et al., 2001)
- Short rotation period (6-8 years)

- High CO₂ exchange rate (Nelson, 1984)
- High water use efficiency (Dickmann and Keathley, 1996)

4. Silviculture of poplars

4.1 Nursery Practice: Nursery techniques for raising poplars have been conducted at Forest Research Institute, Dehradun and guidelines prepared are given as under. The same technique is applicable to all *Populus* species planted in India.

4.1.1 Preparation of cuttings

Poplars are generally raised by vegetative means using cuttings. Cuttings are derived from one year old shoots from lower two-third portion or from nursery grown one year old plants, during the dormant season. Cuttings from the shoots are prepared using sharp cutters like secateurs. The optimum diameter of cuttings (22 cm long) varies from 1-3 cm. Cuttings can safely be drawn at any time from the middle of January. Both ends of the cuttings should be sealed by wax as protection against moisture loss. The cuttings must be submerged in fresh water immediately after preparation and kept for 28 hours prior to planting, cuttings should be drenched with Aldrin (30 EC thoroughly mixed in 100 litre water emulsion. Thereafter the cuttings are also treated with Emisan – an organomercurial fungicide (250 gm Emisan in 1000 litre of water).

4.1.2 Planting of cuttings:

The cuttings are inserted vertically in well prepared nursery beds. The usual spacing between cuttings is generally kept at 50 cm or 60 cm and between rows 60 to 80 cm. The entire length of cuttings should be inserted into the soil keeping one bud above ground level. The soil around each cutting should be compacted gently but firmly without injuring the bark. The nursery raised plants called Entire transplants (ETP's) attain a height of about 3 to 4 meters in one growing season. These are utilized for planting in the field.

Table 1. Important countries undertaking poplar plantations

Countries	
France	Canada
Japan	India
Italy	Pakistan
Korea	Turkey
Hungary	Syria
Yugoslavia	Iran
Australia	Iraq
Romania	Afghanistan
Germany	New Zealand
Netherlands	Morocco
Belgium	Tunisia
U.S.A	Algeria

Table 2. Countries reporting Poplar stand area

Country	Natural Poplar stands area (1000 ha)	Planted Poplar stands (1000 ha)
Canada	28,300	-
Russian Federation	21,900	-
United states	17,700	-
China	2,100	4900
Germany	100	-
Finland	67	-
France	40	236
India	10	1000
Italy	7	119
Turkey	-	130
Argentina	-	64
Total	70,224	6,449

(Ball et al., 2005)

5. Distribution at global level

Poplars in their natural range occur interspersed throughout the forests of temperate regions of Northern Hemisphere between the southern limit of around latitude 30° N and northern limit of latitude 45° N. Several species occur naturally in the land mass. There are 35 species of poplars currently recognized in the world.

Globally, 91% of poplars grow in natural forests, 6% in plantations and 3% in AF systems. China (76%) and India (15.5%) are the major countries having higher planted area.

Table 3. Area trends in different countries

Country	Poplars		
	Natural forest species	Planted	Agroforestry/trees outside forests
Argentina		▲	
Belgium	▼	▼	▼
Bulgaria	▼	●	▲
Canada	●	▲	▲
Chile		●	●
China	▲	▲	▲
Croatia	▲	▼	
Finland	●	▲	
France		▲	
Germany	▼	▼	▲
India	●	●	●
Italy		▲	
Russian Federation	▲	▼	●
Serbia and Montenegro	▼	●	▲
Spain	●	▲	▲
Sweden			
Turkey	●	▼	▼
United Kingdom	●	▲	
United States	▼	▲	▲

(▲, increasing; ▼, decreasing; ●, Stable) (Ball et al., 2005)

The reports by IPC members suggest that the area of planted poplars appears to be increasing globally. Regionally, the area is decreasing or stable in Europe, increasing or stable in Asia, increasing in North America and increasing or stable in South America. The planting of poplars in smallholder woodlots and in agroforestry systems is increasingly enhancing land use in Asia (especially China and India) and South America.

6. Indigenous poplar Species

There are six poplar species Indigenous to India growing along water courses in the higher hills, in

valleys and also on hill sides exposed due to landslides etc. Most of the indigenous poplar species grow in areas having mean minimum and maximum temperature of 6^o C and 10^o C, respectively. They grow well on low lying and moist areas preferring loamy soils but may be planted on river beds with sandy soils and in areas with clayey loams in forest soils. The soil pH best suited to poplars ranges between 5.0 to 6.5. Poplars are known to naturally occur in sub-tropical broadleaved hill forests, wet temperate, moist temperate deciduous forests and dry temperate forests. Their distribution in nature is as follows:

Table 4. Indigenous poplar species distribution

Species	Distribution
<i>Populus ciliata</i>	Temperate and Sub-temperate region of Himalayas; altitude: 1200-3500m.
<i>P. laurifolia</i>	North-west Himalayas; altitude: 2400-4000m.
<i>P. gamblei</i>	Eastern Himalayas (Sikkim, North Bengal, Arunachal Pradesh); altitude: 400-1300m.
<i>P. euphratica</i>	North-west Himalayas; altitude: up to 400m.
<i>P. alba</i>	Western Himalayas; altitude: 1200-1300m.
<i>P. jaquemontiana</i> var. <i>glauca</i>	Eastern Himalayas (Sikkim, North Bengal); altitude: 1500-3200m.

(Tewari, 1993)

Among the six species *P. laurifolia* and *P. gamblei* are fast growing and offer a potential to meet the increasing demand of wood for packing cases and for other industrial uses; *P. euphratica* is seen to be thriving well in the cold desert region of higher Himalayas. Other species grow slow but yield good quality wood.

7. Exotic poplar Species

Since poplars prefer longer hours of day light, the natural zone of poplars lies only from 31^o N latitude and upwards. Therefore exotic poplars were initially introduced in India in areas between 28^o N to 31^o N. Individual plants in the genus *Populus* are either male or female therefore their seeds produce a large number of hybrids. This character offers excellent opportunities for improvement and selection. To produce true to type plants they must invariably be propagated vegetatively.

As a result of research trials with various species of poplars, Forest Research Institute (FRI), Dehradun and State Forest Departments could identify suitable clones of *Populus* species to suit the different agro-climatic conditions in the country. The technology of raising poplar perfected by the FRI scientists has helped popularize the species amongst Forest Departments and farmers within a short span of less than two decades. After initial screening, the State Forest Departments and the industries like WIMCO (Western India Match Company Limited) are provided with the germplasm of the successful clones which they multiply and distribute to the farmers, along with technical know-how on their culture developed at this institute.

In India large number of exotic species/clones have been tested, screened and recommended for raising large scale commercial plantations above 28^o N latitude. Several states have raised commercial plantations of exotic poplars. Suitable clones/ species of *Populus* adapted to the different regions/states are as follows:

Table 5. Suitable Exotic species for different states

State	Suitable Exotic Poplar species
Uttar Pradesh	<i>Populus yunnanensis</i> , <i>P. robusta</i> , <i>P. deltoides</i> 'G-3', 'G-48', 'D-121'.
Jammu Kashmir	<i>P. nigra</i> var. <i>italica</i> , <i>P. euramericana</i> 'I-488', <i>P. eugenei</i> , <i>P. robusta</i> , <i>P. deltoides</i> 'IC'.
Himachal Pradesh	<i>P. euamericana</i> 'I-488', 'I-65', 'I-15', <i>P. Rubrapoiret</i> , <i>P. deltoides</i> 'IC'.
Punjab	<i>P. deltoides</i> 'G-3', 'G-48', 'D-121'.
Haryana	<i>P. deltoides</i> 'G-3'.
Arunachal Pradesh	<i>P. deltoides</i> 'G-3', 'IC'.
Maharashtra	<i>P. deltoides</i> 'D-121', 'G-3', 'G-48'.

(Tewari, 1993)

Some of the new clones introduced recently that have shown success in farming systems in North India are 'ST-67' 'S7C4', 'S7C8'. Clones of 'L' series developed at Haldwani (U. P.) from open pollinated seeds of 'G-48' and 'D-121' have also shown promise and may replace the existing clones in near future.

8. Production potential under different spacings of Poplar

8.1 Production with agricultural crops

An experiment was conducted to study the feasibility of raising poplar in pearl millet-wheat sequence and to work out its irrigation requirement and planting pattern in light textured soils by Kaushik and Jagdev (2001) in Haryana. The planting of one-year-old nursery raised saplings was done at three spacing viz., 5x4m, 8x3m and 10x3m. Irrigations were

provided at an interval of seven days up to one-month of planting. Thereafter, irrigations were applied at an interval of 6(I₁) 12(I₂) and 18(I₃) days during the summer months (April, May and June) in the first year and at an interval of 15 days during the second year. During the crop season the irrigation as per crop need i.e. five in wheat and one in pearl millet were applied both to the crops and trees and no additional irrigation was provided to the poplar plants. The cultivation of crops in interspaces of trees was started in Kharif. During Kharif pearl-millet was raised followed by wheat in rabi season continuously for two years. The above crops were also raised as sole crops. The irrigation interval comprised main treatments while spacings were considered the sub-main treatments with three replications.

Table 6. Effect of poplar spacing on pearl millet and wheat yields

Spacing (m)	Pearl millet				Wheat			
	Grain yield(q/ha)		Straw yield (q/ha)		Grain yield(q/ha)		Straw yield (q/ha)	
	1998-99	1999-00	1998-99	1999-00	1998-99	1999-00	1998-99	1999-00
6 Days								
5x3	10.00	12.60	16.00	18.30	42.20	45.80	43.00	46.90
8x3	10.40	13.40	16.80	19.40	42.70	46.30	43.50	47.80
10x3	11.30	14.00	17.50	20.50	43.00	46.90	44.00	48.00
12 Days								
5x3	10.10	12.80	16.10	18.90	42.10	46.00	42.90	47.10
8x3	10.90	13.70	17.00	19.70	42.90	46.80	43.80	47.60
10x3	11.60	14.60	18.00	20.90	43.00	47.00	44.00	48.00
18 Days								
5x3	10.30	12.90	16.30	19.00	42.30	46.00	43.20	47.00
8x3	11.40	13.70	17.00	20.00	43.20	47.00	43.70	47.70
10x3	11.50	14.50	17.90	20.80	43.50	47.00	44.20	48.20
Sole cropping	12.00	15.00	19.00	22.00	44.00	48.00	45.00	49.50
CD (P=0.05)	NS	1.60	NS	2.80	NS	NS	NS	NS

(Kaushik and Jagdev, 2001)

The plant unit per replication was three and per treatment were nine. The data on growth parameters of poplar (i.e. height, basal diameter and diameter at breast height) was recorded and subjected to split plot design for statistical analysis. Grain and straw yield of wheat and pearl millet was recorded and analyzed according to randomized block design with three replications (Panse and Sukhatme, 1967).

The influence of tree spacings on the yield of pearl-millet during the first year was not significant. Maximum grain and straw yields of pearl-millet were recorded under sole cropping. The grain and straw yields of pearl-millet were significantly less under 5x3m geometry as compared to sole cropping during second year. The grain and straw yields of wheat were maximum in sole cropping. However, the yields obtained under various plant geometries of poplar were statistically at par to sole cropping treatment. This

might be due to the fact that poplar did not cause any shading effect on wheat because shedding of leaves of poplar occurred during the winter season. In the initial years of planting the poplar trees, there is every possibility to produce Pearl-Millet-Wheat in the irrigated, arid and semi-arid parts of southern zone of Haryana. The poplar plantation can be grown /established successfully by providing irrigation at an interval of 6 and 12 days during summer months in the first year of establishment and at an interval 15 days during second year of establishment.

Nandal and Hooda (2005) experimented to identify and screen suitable agricultural crops under different spacing of poplar. A field study was conducted for seven years (1995 – 2002) at the Research Farm of Forestry Department, CCS Haryana Agricultural University, Hisar. Poplar (G₃) saplings were planted at 5 x 4 m, 10 x 2.5 m and 15 x 2.5m

spacing. Poplar plants were pruned to 50 percent of the total height every year in the month of November.

The experiment consisted growing of different crop combinations in three alley spaces of poplar and one control i.e. without poplar. The crops were replicated thrice in a randomized block design with plot sizes of 5 x 4 m, 5 x 5 m and 7.5 x 5 m, in 5 x 4 m, 10 x 2.5 m and 15x 2.5m spaced poplar and control,

respectively. Agricultural crops were raised for seven consecutive years. The comparative performance of crops is expressed in terms of per cent relative yield obtained in treated plot with crop yield obtained in control. Important growth and yield attributing characters of crops were recorded at the time of crop harvest.

Table 7. Fodder and grain yield (q/ha) of rainy season crops under different spacing of poplar

Crops	Years	Tree spacing (m)			Control
		5x4	10x2.5	15x2.5	
Sorghum	1996	195 (55)	292 (82)	320 (90)	354
	1997	40 (14)	115 (42)	123 (44)	277
	1998	65 (22)	120 (41)	140 (48)	294
	1999	44 (15)	118 (40)	127 (44)	292
	2000	32 (11)	110 (39)	113 (40)	281
	2001	14 (4)	114 (35)	122 (38)	325
Cowpea	1996	132 (60)	186 (84)	201 (91)	220
	1997	93 (43)	175 (81)	186 (86)	215
	1998	65 (27)	150 (63)	155 (65)	238
	1999	31(15)	123 (58)	136 (64)	212
	2000	35 (22)	78 (50)	82 (53)	156
	2001	73 (20)	187 (51)	215 (58)	370

Figures in parentheses indicate per cent relative yield (Nandal and Hooda, 2005)

In general, yield of all crops decreased with advancing age of poplar due to increased competition for growth resources like sunlight, moisture and nutrients. Active growth and full foliage of the trees during the rainy season offered maximum competition with crops for growth resources. The yield of all crops increased with increasing row spacing from 5x4m to 15x2.5m. It may be ascribed to increased sunlight availability and decreased competition for moisture and nutrients between crop and tree roots. On the account

8.2 Production with other crops

of competition for growth resources, yield of all test crops during the first year decreased under different spacing of poplar as compared to control. It was mainly due to decreased light availability to crops under poplar.

Cowpea recorded maximum relative yield at all the poplar spacings during the entire rotation cycle. The reduction in the yield of sorghum and cowpea was due to reduced plant height and development of thin stems under poplar.

Table 8. Green matter, tuber and rhizome yield (q/ha) of crops under different spacing of poplar

Crops	Years	Tree spacing (m)			Control
		5x4	10x2.5	15x2.5	
Dhaincha	1997	34 (10)	106 (33)	121 (38)	321
	1998	45 (14)	100 (32)	136 (43)	312
	1999	22 (11)	52 (25)	78 (38)	204
	2000	21 (9)	62 (27)	71 (31)	228
	2001	31 (10)	53 (18)	99 (33)	300
Potato	2000	96 (60)	104 (65)	125 (78)	160
	2001	60 (50)	84 (70)	84 (70)	120
Turmeric	2000	26.8 (50)	52.9 (98)	0 (0)	54.0
	2001	25.0 (45)	48.8 (88)	0 (0)	55.7
	2002	31.0 (39)	70.0 (88)	0 (0)	80.0

Figures in parentheses indicate per cent relative yield (Nandal and Hooda, 2005)

The yield of the crop increased with increasing row spacing from 5 x 4m to 10 x 2.5m. It may be ascribed to increased sunlight availability and decreased competition for moisture and nutrients between crop and tree roots. During winter season the trees shed their leaves and become almost dormant resulting in negligible competition for growth resources particularly sunlight. Turmeric grown after the onset of severe competition for growth resources from 2000 onwards recorded maximum relative yield under both the spacings of poplar. Turmeric yield under 5 x 4 m spacing decreased mainly due to less number of rhizomes/plant. Dhaincha grown for green manuring produced least yield of green matter. Potato crop had to be abandoned after growing for two years because of small tuber size fetched less price.

9. Constraints in poplar based agroforestry system

9.1 Germplasm collection and its evaluation.:

The present situation of poplar cultivation invites special attention of the researchers in view of its narrow genetic base in India. It is estimated that around 90 per cent poplar cultivation in Uttar Pradesh, Haryana and Punjab is done using three clones namely G3, G48 and S7C15. The growth of clone G3 has declined due to its susceptibility to blight (caused by *Bipolaris maydis*) and G48 is in a declining trend. In order to sustain the expanding commercial cultivation of poplar, a continuous back-up of research is needed.

9.2 Shallow root system: The species has a shallow root system with many highly branched lateral and fine roots throughout the soil profile. This leads to competition with the component crops for water, nutrients, etc. Therefore clones with deep rooting system should be introduced.

9.3 Poplar is competitive to component crops: As poplar is fast growing and shallow rooted species it competes with the component for space, light and water, thus resulting in reduced crop yield.

9.4 Lack of drought, flood and salt tolerant clones of poplar

9.5 Lack of knowledge of cultivation of poplar

10. Approaches to improve productivity of poplar based agroforestry systems

Inter and intra specific breeding and introduction of new species should be undertaken to broaden the genetic base. Most adaptable clones for different site conditions should be identified through multi-localational trials. Suitable combinations of agricultural crop varieties and poplar clone should be identified for cultivation in order to minimize the losses in crop yield. Need to train the farmers for achieving higher productivity and for developing farmer's cooperatives for disposal of poplar wood.

11. Conclusion

Poplar based agroforestry systems play an important role in the socio-economic development of people in North India. They help in meeting the growing demand for timber, fuelwood and fodder. Both indigenous as well as exotic species are cultivated for meeting the demands. Poplars have the features which are suitable for agroforestry systems. Agricultural crops are more compatible with poplar in the initial years. In the later stages of poplar growth the yield of agricultural crops is substantially reduced. But the income from the system as a whole is increased as the loss in yield of agricultural crops is compensated by increased yield and price of poplars. Suitable combinations of agricultural crop varieties and poplar clone should be identified for cultivation in order to minimize the losses in crop yield. Poplar based agroforestry systems provide about Rs. 40,000 per year per acre which is approximately three times more than the rice-wheat rotation in central plains of Punjab. This has boosted the economy of the poplar growers, and helped in the development of plywood industry in the state. This poplar based agroforestry system is economically more viable and more profitable than many of the crop rotations. It is also capable of providing continuous employment on farms and preserving ecological system as well. There exists plenty of scope for improving the output and income from poplar based agroforestry system through intensive management practices and application of optimum levels of inputs.

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