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Poplars in India

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Status of Poplar Culture in India

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Introduction

Poplar culture in India is mainly taking place on the farmland in parts of the northern India, though a very small percentage is also planted on the forest land by the state forest departments in and around the Himalayan ranges. Introduction trials of poplar species and clones were tried 1950 onwards in the state of Uttar Pradesh and some other states (Chaturvedi, 1982 a and b). The tree is, however, being regularly promoted on farmers' fields by WIMCO – a safety match company since 1976 (NAEB, 1993; Jain and Singh, 1999; Dhiman, 2008a). A number of private nursery growers and a couple of state forest departments also contribute in supplying a sizeable number of saplings to the growers for making fresh plantations. Increased wood availability from WIMCO's promoted programme encouraged establishment of other wood based industrial units in and around its growing region. Due to the increased demand of poplar wood, its trade expanded in the unorganized sector and accordingly its culture. Poplar culture and usage are now fully merged into the social, ecological, agricultural, silvicultural, economical and industrial applications, which are immensely helping in the economical transformation of growers and the region. Poplar is generating goods that include timber, firewood, fodder, leaf manure, etc. The use of poplar wood is now diversified to around three dozen products of which panel products, firewood, paper pulp, match splints, sports goods, artificial limbs are the major ones (Dhiman, 2008b). Its farming helps in sequestration of harmful gases into wood biomass and soil, locking greenhouse gases in products made from its wood; substituting sustainably grown firewood for fossil fuels in domestic and industrial use; bioremediation of soil, air and water by absorbing pollutants; conserving soil and water along the ecologically sensitive river basins of Ganga, Yamuna, Satluj, Beas, Sharda and their tributaries; and reducing industrial effluent load in paper industry by using poplar pulpwood that requires less chemicals in processing in comparison with the traditional pulp woods. Poplar culture also improves water use economy by shifting growing of high water demanding paddy crop to low water demanding agriculture crops grown inside poplar plantations. It has improved living conditions of rural people by generating an employment potential of approximately 100 million man days in poplar related activities mostly in rural locations (Dhiman, 2008b) and further sustaining the agricultural production

A major share of poplar is grown in parts of Punjab, Haryana, Uttarakhand, Uttar Pradesh and some adjoining states and these locations have been collectively designated as the region of intensive poplar culture (RIPC)

system by shifting from the monotonous paddy-wheat rotation to ecologically more sustainable and integrated multiple cropping land use with sylvan landscape. Poplar culture in India is assessed to yield approximately 7.5 Mt timber, 1 Mt pulp wood, approximately 5 Mt firewood (also includes wood wastage from industry) and sequestration of approximately 2.50 MtC per annum (Dhiman, 2009) based on planting and harvesting of 20 M trees per annum on 10 yrs average basis. The planting number of its saplings is now increased to over 30 million and, therefore, the benefits of goods and services from its culture have also increased (Table 5 and 6). This paper summarizes the present status of poplar culture especially on volume of its nursery production and fresh plantations made during 2011-12.

Trends in Poplar Nursery and Plantation Culture

Poplars are one of the first tree species which were grown in the hills for getting firewood, fodder and small timber for local consumption. Occurrence of approximately 600-yrs old *P. balsamifera* tree in Leh town (Fotidar, 1983) and that of other trees of this and other species in Jammu and Kashmir (J. and K.), Himachal Pradesh (H.P.) and Arunachal Pradesh (Naithani and Sumer Chandra, 1999; Chauhan and Lakhanpal, 2000) confirms poplar being grown in hills for centuries. Some poplar trees recorded in and around Budhist temples (Gompas) also indicates their sacred value in India (Dhiman, 2010a). A major share of poplar is grown in parts of Punjab, Haryana, Uttarakhand, Uttar Pradesh and some adjoining states and these locations have been collectively designated as the region of intensive poplar culture (RIPC) (Dhiman, 2012). RIPC stretches from western limits in Punjab to eastern limits inside north western Bihar and from north near foot hills of Himalayas down towards north central Haryana and Uttar Pradesh. Poplar culture in this region is based on indigenously developed and introduced cultivars of *P. deltoides*. Some other introduced and indigenous species planted on a limited scale in the central and inner Himalayas especially in the cold arid region of Jammu and Kashmir and Himachal Pradesh states are *P. nigra, P. alba* and *P. balsabifera*. Many productive clones of *P. deltoides* have now been introduced in the cold arid region during the last three decades, and this species is now preferred over other poplar species because of its fast growth almost everywhere. *P. ciliata* and *P. gamblei* are the poplars indigenous to Himalayas and some of their plantations have been made on forest land for diverse forestry purposes.

A major share of poplar is grown as a cash crop similar to many agricultural crops. Spread in its nurseries and plantations depends on market wood prices and the trends, till date, indicate increase in its culture with increase in valuation of its wood. Both the market wood prices and its fresh plantations have been increasing since 2005. Within the RIPC and elsewhere, the intensity of poplar culture is concentrated in certain locations. Poplar culture within each district, location, state and RIPC is not uniformly distributed and there are imbalances in its spread. Poplar growing locations in each state have been categorized into excellent, large, medium, low, and rare/casual levels based on the volume of planted poplar in those locations (Table 1).

There are three distinct and concentrated zones of poplar culture within the RIPC around which maximum poplar is grown in the country. The two zones located on the western side of poplar culture lie around the river basins whereas the third lies in the Tarai region of Uttarakhand and

Table 1. Intensity of poplar culture in different districts of India

S. no.	Scale	Jammu and Kashmir	Himachal Pradesh	Punjab	Haryana	Uttarakhand	Uttar Pradesh	Bihar	Rajasthan
1.	Extensive			Hoshiarpur, SBS Nagar, Roop Nagar, along the river banks of Beas and Sutlej	Yamunanagar	Udham Singh Nagar and Haridwar	Saharanpur, Muzaffarnagar, Bijnor, Meerut, Rampur, Bareilly, Pilibhit, Moradabad, Jyotiba Phule Nagar		
2.	Large	Central Kashmir		Amritsar, Gurdaspur, Jalandhar, Kapurthala, Ludhiana	Karnal, Panchkula, Ambala, Kurukshetra		Baghpat, Amroha, Badaun, Shahajahanpur, Kheri		
3.	Medium	North Kashmir, South Kashmir	Una, Kangra	Pathankot, Moga, Mohali	Panipat, Kaithal	Dehardun and Nainital	Bulandshahr,, Bahraich, Sitapur, Hardoi, Gautam Budh Nagar	Vaishali	
4.	Low	Kathua and Poonch of Jammu region; Ladakh and Kargil of Ladakh region	Sirmour, Solan, Mandi, Lahaul and Spiti	Tarantaran, Firozpur, Patiala, Mukatsar, Fazilka	Sonipat, Rohtak, Faridabad	Pauri Garhwal and Champawat (Tanakpur area)	Maharajganj, Kushinagar, Gorakhpur, Etah, Aligarh, Sidharath Nagar, Sravasti, Balrampur, Deoria, Balia	Muzzafarpur	Ganga Nagar
5.	Rare	Other districts	Other districts	Bathinda, Barnala, Sangrur, Mansa, Fatehgarh	Hissar, Sirsa, Fatehabad, Gurgaon, Jind	Other districts	Kanpur, Agra, Lucknow, Faizabad, Sulatanpur, Azamgarh, and others	Champavat	Hanumangarh Bharatpur

Uttar Pradesh states. Adequate water availability within these zones and deficit around their boundaries appear to make this distinction in poplar culture. The first zone of concentrated poplar culture lies towards the western limits along the basins of rivers Satluj and Beas in Punjab with some overlapping in plain locations of Himachal Pradesh. The land around and between these two rivers is ideally suited for poplar farming because of easy water availability and sandy loam soil conditions. This zone lies towards higher latitudinal limits within the RIPC and is better suited for poplar culture in comparison with two other zones. It starts around Hoshiarpur in Punjab and extends towards Chandigarh through SBS Nagar and Rupnagar districts on one side and towards Ludhiana district on the other side. The growth and quality of poplar grown in this zone is better and it fetches higher prices in the market. The second major activity of poplar culture is seen around Yamuna and Ganga Rivers and surrounding their basins starting from Himalayan foothills down towards central Haryana and central Uttar Pradesh. This zone overlaps in three states, viz., Haryana, Uttarakhand and Uttar Pradesh and has maximum area under poplar farming. This zone is at a little lower latitude than the first zone, yet has maximum number of wood processing industries and also receives poplar wood from other locations and states. It constitutes Yamunanagar District of Haryana, Saharanpur and Muzaffarnagar districts of Uttar Pradesh and Haridwar District of Uttarakhand.

Zone-III lies in the plain region near foothills of Uttarakahnd and Uttar Pradesh states and known as Tarai region. It is a narrow belt between 27°N and 30°N latitudes at an altitude of about 160 to 260 m, along the foothills of Himalayas where water is available at a depth of 1 to 2 m below surface with further having underlying layer of sand and small pebbles to varying degrees. Unlike other two zones, soil at places is very heavy, yet it supports poplar culture on account of good water availability. Poplar (*P. deltoides*) were initially tested here before their culture was extended to other zones and locations in the RIPC and elsewhere. The zone lies in Udham Singh Nagar in Uttarakhand, and stretches to parts of Uttar Pradesh in Pilibhit and Bareilly on one side and some parts of Rampur on other side. The data gathered on fresh poplar plantations made during the last two years indicates that two third to three fourth of the total poplar planted throughout, is in these three zones. Around 29 per cent of total poplar is planted around Zone-II, 22 per cent around Zone-I and around 18 per cent around Zone-III. Recently, the share of fresh plantations has started increasing in the third zone because many new poplar based wood industrial units have been established in Uttrakhand and many others have expanded their capacity in Uttar Pradesh. Prices of poplar wood and labour wages are lower in Zone-III favoring increased poplar farming and its usage.

Extent of Nursery Production

Poplar is grown on non-forest land in many states for which a complete data on the volumes of its saplings production is not available. Till 1994, most of its plantations were grown by the farmers under WIMCO-NABARD refinance scheme. WIMCO was responsible for supplying its saplings to the growers under this project, which is also referred as PPP model, and the wood grown from these trees was purchased back by the company at already disclosed prices. The company was, therefore, the only source for supplying the saplings to the growers till that stage. The number varied from a few hundred in 1976-77 to around 250 thousand during mid 1990s. On termination of WIMCO-NABARD scheme, and with the success of the direct sale of saplings outside, the refinance scheme was started by the company in the year 1993, poplar sapling production expanded among the numerous nursery growers. It also provided opportunity to the separating company staff with technical skills to venture into growing and selling poplar saplings to the growers. As a result, the business of establishing private nurseries started growing. WIMCO, ex-Wimcoites, individual farmers and unemployed villagers are presently the main nursery growers. Haryana State Forest Department has now accelerated its sapling production on increasing demand within the RIPC and elsewhere. Jammu and Kashmir, a hilly state with most of its area land locked between hill ranges, has also started growing sizeable number of poplar saplings for local planting by the growers. There is migration of some of the poplar based industry to this state because of low value of wood available there, which has increased the rate of planting and demand of its saplings within Kashmir Valley. State forest departments in North India have also been growing poplar saplings for making their own plantations on forest land during this period. Some information on the availability of planting stock in U.P. State Forest Department nurseries is accessible from the state website (http://forest.up.nic.in/plantation.pdf) (Table 2). Similarly a detailed survey of poplar nurseries carried out by the Haryana State Forest Department during 2011-12 provided information on the extent of nursery stock grown in that state (Dhiman and Jagdish Chander, 2012).

The total poplar nursery stock presently available in the U.P. State Forest Department nurseries is given in Table 2 indicating that poplar constitutes less than 0.1 per cent (84,099 saplings in 52 nurseries) of the total planting stock (87,632,706 number for 72+ other species in 925 nurseries

of 72 forest divisions) grown in the state. The major share of poplar nursery and plantation production in the state is in the private sector which grows poplar saplings as naked root plants in open beds and are called as entire transplants (ETPs) or saplings. Conservative estimates indicate that the private sector has grown around 15 million nursery saplings during the just concluded planting season in the state (Table 2). Among the private nursery growers, WIMCO is a leading player in nursery production throughout the RIPC and is growing 6.5 million saplings this year in its nurseries located in the RIPC. The company has been monitoring the extent of poplar nurseries grown by different sources in different states through its field staff. The information on nursery stock is collected from its field staff posted throughout the RIPC and the estimates of total poplar saplings grown in the state of Uttar Pradesh are given in Table 3. The names and the boundaries of WIMCO's operational districts do not synchronize with that of the administrative and revenue districts as per government controls but are overlapping with the adjoining districts in many locations.

Haryana is one of the leading states in poplar wood usage and also grows appreciable number of saplings for planting within the state and also for supply to some other states (Dhiman and Jagdish Chander, 2012). A detailed survey of all the poplar growing nurseries was carried out by the Haryana State Forest Department which confirms growing of approximately 13.4 million poplar saplings during the year 2011-12. A major share is grown in the private sector by small nursery growers (Table 4). In the organized sector, WIMCO and the state forest department were the leading nursery growers in term of number and diversity of clones grown in the state. Yamunanagar town is a major poplar growing and its usage centre in the state and the country. Yamunanagar District grows around 60 per cent of total poplar grown in the state. The district is also a main centre for seedling production and their supply to the adjoining states. It receives wood from all other poplar growing states including Punjab, Himachal Pradesh, Uttrakhand and Uttar Pradesh and wood traders also supply saplings to many wood procuring locations.

Uttrakhand state (earlier part of U.P.) has been growing poplar saplings from the very beginning when poplar research trials were initiated by the state forest department during the second half of 20th Century. The focus of the poplar programme in the state remained with testing of imported clones and development of mechanized plantations in and around Tarai region. The state has been growing poplar nurseries for own plantations on forest land near Kumaun foothills since 1970s. Presently, the state is growing around one hundred thousand saplings in its nurseries for own

Table 2. Poplar stock existing in the nurseries of U.P. State Forest Department

S. no.	Forest Circle	Forest Division	Nurseries (no.)	Plant stock (no.)	Average stock (per nry)
1.1	Agra	Firozabad	1	2,000	2,000
1.2		Mainpuri	1	558	558
2.1	Allahabad	Allahabad	1	700	700
2.2		Fatehpur	1	4,400	4,400
3.1	Azamgarh	Azamgarh	1	300	300
3.2		Baliyaa	4	1,965	491
3.3		Mau	4	1,816	454
4.1	Bareilly	Bareilly	15	49,776	3,318
4.2		Pilibhit SF	1	300	300
4.3		Shahajahanpur	1	293	293
5.1	Basti	Basti	1	1,000	1,000
6.1	Faizabad	Ambedkar Nagar	4	2,825	706
6.2		Faizabad	2	1,360	680
6.3		Sultanpur	8	10,000	1,250
7.1	Gorakhpur	Gorakhpur	2	8,600	4,300
8.1	Kanpur	Etawa	2	1,050	525
8.2		Dehat	2	850	425
9.1	Meerut	Bulandshahar	1	301	301
		Total (U.P.)	**52**	**88,094**	**1,694**

(Source: http://forest.up.nic.in/plantation.pdf).

Table 3. Estimated poplar planting stock produced by private growers in U.P. (2011-12)

S. no.	District	Locations	Stock grown (no.)
1.	Saharanpur	Saharanpur, Nakur, Deoband, Rampur	3,100,000
2.	Muzaffarnagar	Muzaffarnagar, Deoband, Barla, Bhopa, Jansath	450,000
3.	Meerut	Hastinapur, Mawana, Hapur, Garh, Ghaziabad, Sardana, Baghpat	1,300,000
4.	Bulandshahar	Toria, Khalout, Bateshwar (Agra)	300,000
5.	Agra	Bateshwar	50,000
6.	Aligarh	Atrauli	100,000
7.	Moradabad	Moradabad, Amroha	800,000
8.	Bijnor	Dhampur, Chandpur, Nurpur, Afjalgarh	600,000
9.	Rampur	Milak, Rampur, Chandaushi, Bilaspur, Kemri, Muda Pandey	3,400,000
10.	Bareilly	Bareilly, Baheri and Meerganj, Aonla, Faridpur, Bhojipura	1,050,000
11.	Pilibhit	Majhoula, Bisalpur, Tikri, Amaria, Khamria	550,000
12.	Badaun	Dataganj	150,000
13.	Sahajahanpur	Kot, Tilhat, Katra, Shehramau, Puvaya, Khutar, Nigohi, Bhawal Khera	550,000
14.	Lakhimpur	Lakhimpur, Dharaura, Palia	400,000
15.	Sitapur	Tambore, Sitapur	100,000
16.	Bahreich	Nanpara, Payagpur, Kesarganj, Econa, Bahreich	850,000
17.	Hardoi	Kothava, Badhauli, Sadabad, Pali	200,000
18.	Others		1,200,000
	Total		**15,150,000**

planting. Wimco Seedlings operates from Rudrapur, Uttrakahnd and is still the main player for supplying saplings to the growers along with some ex-Wimcoites and other small growers. Maximum private nurseries are located in Udham Singh Nagar and Haridwar districts, some of which also supply saplings to other states.

Punjab is the fourth leading state in poplar sapling production in the country. It grows nurseries in different locations. Around one hundred thousand saplings are grown by the government institutions that include Punjab Agricultural University, Ludhiana and the Punjab State Forest Department, together. The major share of sapling production is in the private nurseries located in Hoshiarpur, SBS Nagar and Roopnagar districts in the state. Some saplings are supplied to the adjoining poplar growing locations in Himachal Pradesh and Jammu and Kashmir states.

Table 4. Poplar saplings grown in Haryana state during 2011-12 planting season

S. no.	District	Nursery stock	Share (%)
1.	Yamunanagar	8,129,300	60.51
2.	Kaithal	37,500	0.28
3.	Karnal	1,766,000	13.15
4.	Panipat	961,000	7.15
5.	Rohtak	37,000	0.28
6.	Sonepat	220,000	1.64
7.	Panchkula	880,500	6.55
8.	Ambala	1,168,500	8.70
9.	Kurukshetra	234,000	1.74
		13,433,800	**100.00**

Jammu and Kashmir (J. and K.), a hill state, has traditionally been growing poplar. The state grows approximately thirteen to fourteen hundred thousand poplar saplings in the state. Recently, restrictions on transporting planting stock and wood across the state border have been imposed, hence, most of the planting stock is grown within the state itself. Some supplies of the planting stock, however, still take place from the adjoining RIPC to Jammu region where the tree is grown similar to that grown in the RIPC. Private nurseries now grow little more saplings compared to those grown by the Social Forestry Wing of the state forest department. Major share of private nurseries is concentrated in south Kashmir followed by central Kashmir, north Kashmir and Jammu region and Ladakh region. Many cities and locations in Kashmir Valley are affected by typical cotton storms during the dispersal of its seed in spring season. In

the last couple of years, the Jammu and Kashmir State Forest Department and state university have been procuring the propagation material of male clones from WIMCO for raising their nurseries and field planting to avoid this problem.

The state of Himachal Pradesh (H.P.) has been making planting of around one hundred thousand saplings on the forest land and this planting stock is grown by the state forest department in its forest nurseries. A major share of the planting stock planted by the growers in the plain and in some valley areas of Himachal Pradesh is supplied by the private nursery growers from the adjoining poplar growing locations, like Hoshiarpur, Roopnagar, and Pathankot districts in Punjab and Yamunanagar and Panchkula districts in Haryana. The major part of poplar wood harvested in the state is traded at Yamunanagar wood market in Haryana and Hoshiarpur in Punjab. Both these locations are leading centers for poplar sapling production as well. Wood traders who transport wood from different locations of the state also carry saplings from these locations and supply them to the growers during the planting season. Many of good growers especially near the RIPC also directly procure planting stock from the branded nurseries located in the RIPC. Some private nurseries have also come up in Indora belt of Kangra, plain areas of Una District, Nalagarh area of Solan District, Paonta Valley of Sirmour District and Balh Valley in Mandi District to meet the increasing demand of the growers.

In Bihar, poplar saplings have been grown under the centrally sponsored project implemented by the Indian Council of Forestry Research and Education through its institute at Ranchi wherein approximately four hundred thousand saplings were grown in Vaishali District during last year. The state is also planning a Green Mission in which poplar is considered one of the potential species. A few poplar growers in the north Bihar have, however, been directly getting the planting stock from the RIPC for making plantations during the last two decades.

Some poplar saplings, in private and government nurseries, are also grown in Chandigarh, Delhi, Rajasthan, and even some northeastern states. There is also a regular movement of poplar saplings from the RIPC to central, north eastern states and other locations during the planting season each year.

Extent of Fresh Plantations

Poplar has been regularly planted in number of states and locations. Major among them have been hill states of Uttarakhand, Jammu and Kashmir, and Himachal Pradesh where poplar trees in isolated form or in groups could be seen in almost all the hilly districts. Poplar has also been planted in some parts of Delhi, Chandigarh, Rajasthan (Ganganagar, Hanumangarh, Bharatpur districts), north Bihar (Vaishali, Muzzafarpur, Samastipur, Champaran, etc.), north West Bengal and other northeastern states for quite some time now. Poplar plantations on forest lands have mainly been restricted to Uttarakhand and Himachal Pradesh states with some of them grown on road and canal sides, and railway-lines in some states in the RIPC and in hills. Some trial plantations of poplars have also been made in many other central and southern states with suboptimal field performances not at par with that grown in the RIPC.

Some figures of poplar plantations on forest land are available from Uttarakhand and Himachal Pradesh. First organized poplar introduction trial plantations were raised in hills and foothill locations of Uttarakhand (earlier part of Uttar Pradesh). The state of Uttarakhand played a significant role in the introductions, establishment and expansion of poplar programme in the country. There were sporadic plantations till 1977 and thereafter, a regular planting was included in the working plans of some of the forest divisions. The trial with introduced clones were tried near foot hills in 1966 and the growth and productivity of those clones was not very encouraging. G3 and G48 clones were introduced 1969 onward which proved very productive for these locations. There was 1,522 ha area under poplar plantation till 1982 (WoP, 1982) and around 3,500 ha by 1999 (Burfal, 1999). Later on Wimco Seedlings established its research base in Rudrapur which helped in its further establishment and expansion of the programme on farm fields.

Himachal Pradesh State Forest Department has been planting poplar since long. *P. ciliata* is largely planted on forest land by the state forest department and to some extent by the research organizations in their research trials. The interest in poplar as a plantation species dates back to 1950s when planting of *P. ciliata* along with some introduced species were explored as a nurse crop for regeneration of fir and spruce forests in the state (Agarwal and Patil, 1956). *P. ciliata* with introduced *P. monilifera* and *P. generosa* were tried and proved useful in regenerating fir and spruce in Kullu District but could not be replicated on a large scale. *P. deltoides,* is the main preferred species in poplar culture in the state. It finds favour among all growers, viz., farmers, state forest department and research organizations for growing in locations from cold desert to Himalayan foot hills and valley areas. It is mainly planted in Balh Valley of Sundar Nagar, Mandi District, Mand belt (Indora Division) of Kangra District, lower areas of Una District, Nalagarh Division of Solan District and Paonta Valley of Sirmour District. The

species was also introduced in the Spiti cold arid region during early 1980s and some of its plantations are better grown than many plantations of other species. The main cultivars of poplar commercially grown in the state are the same which are grown in the RIPC. These include G48, Udai, WSL 22, WSL 39, etc. with some last year released clones specifically WIMCO 81, WIMCO 83 and WIMCO 110 are also now finding favour among the growers. UHF has developed and recommended some clones of poplar for growing in the state (www.yspuniversity.as.in).

Himachal Pradesh has documented plantation figures of poplar and other tree species made from 1950s and posted them on its website (http://himachal.gov.in). Out of a planted area of 1,026,776 ha under different schemes till date (w.e.f. 1950 to 2009-10), poplar plantations cover 14,958 ha which represents 1.46 per cent of the total plantations made in the state so far. Many of the species planted in the state are slow growing conifers and broadleaved species, the share of poplar and willow planted area is, therefore, likely to be very low as most of the earlier planted poplars could have lived their physical age or could have been harvested. The tree is highly sensitive to moisture status of planted sites, the initial and final survival is likely to be lower than the hardy conifers and some broad leaved trees. The state raises plantations with around 20 million plants per year, out of which poplar constitutes 0.58 per cent of total planting. During the last two years, there were 21 plantation schemes, out of which poplars were planted in 12 schemes. CAT plan had maximum plantation of poplars (28.40 per cent) followed by backward area sub plan (19.37 per cent), improvement of tree cover (12.93 per cent), plantation under MHWD project (9.08 per cent), soil conservation (7.61 per cent), enrichment planting (5.83 per cent), compensatory plantations (5.31 per cent), pasture development (4.57 per cent), reforestation of scrub areas (2.95 per cent), macro management (RVP) (1.66 per cent) and FDA samridhi yojna (0.56 per cent) (http://himachal.gov.in). Circle-wise data of poplar planting during these two years further confirm that poplar is planted for diverse purpose. Bilaspur and Hamirpur forest circles located in the lower Himachal Pradesh have some poplar plantations by the private growers though government figures do not show any planting in those areas. The plantation figures further confirm poplar planting under wildlife and watershed programmes. Kullu Forest Circle leads in the state with planting of 41.18 per cent of total poplar on government forests followed by Rampur (20.22 per cent), Shimla (9.70 per cent), MHWD Project (9.08 per cent), Wildlife Shimla (8.26 per cent), Nahan (5.96 per cent), Chamba (4.19 per cent), Dharamsala (0.76 per cent), wildlife Shamshi (0.76 per cent) and wildlife Dharamsala (0.27 per cent) of the total poplar planted in the state (http://himachal.gov.in). Poplar was one of the main tree planted in a centrally sponsored programme - Desert Development Project which was launched for Spiti Division of Lahaul and Spiti District in 1978 and for Pooh Division of Kinnaur District in 1982 with special emphasis on rehabilitation of cold desert. Under this programme, 1,636,735 plants were planted over 830 ha (Negi *et al.*, 1996).

Two regional centers of UHF, viz., RHRS, Jachh and HRRS, Dhaulakuan and its main campus at Solan have been producing poplar saplings for own use and to supply them to tree growers of the locality since mid 1990s. According to Chauhan (2012) Jachh and Dhaulakuan centers have produced and supplied 89,207 and 163,305 saplings respectively till date (total 252,512). The annual supply is worked out to be 8,600 saplings from Dhaulakuan and 5,500 saplings per year from Jachh, respectively. The university had a saleable stock of around 800 fully grown poplar trees that was put to auction during 2011. Himalayan Forest Research Institute is also raising poplar and willow nurseries which have been established in different locations including cold desert region. Some poplar has also been planted by the Public Works Department (PWD) along road side especially along national highway around Solan town.

Major share of poplar in India is planted in the RIPC. Though planting season is restricted to winter months, its harvesting and usage is spread throughout the year. It is harvested, transported, traded and used on day to basis. Harvesting decisions are driven by financial needs of individuals than strong silvicultural options. It is extremely difficult to capture these frequent changes from such a wide geographical area controlled by many states. This many a times has already affected the industry and growers by widening gap between demand and supply and also in crashing of its prices due to glut like situation in the market. National Poplar Commission, quoting Forest Survey of India, has reported 312,000 ha area under poplar in the country (NPC, 2012). Forest Survey of India first time reported inventory of 75,807,000 number poplar stems (with further classification into size classes as 74,150,000 in 10-30 cm dbh class, 1,644,000 in 30-50 cm dbh, 7,000 in over 50 cm dbh class) in its 2011 report which collectively represent 1.50 per cent of total stems recoded as ToFs in the country. The report further confirms the volume of 11.159 mm^3 of poplar trees in 10-30 cm dbh, 1.260 mm^3 in 30-50 m dbh and 0.023 mm^3 in over 50 cm dbh class for all the poplar trees as ToFs in the country. The total volume of poplar trees as ToFs is reported as 12.402

mm^3 representing around 0.8 per cent of total volume in ToFs in the country (IFSR, 2011). The districts once selected for surveying is likely to be surveyed after 10 cycles (20 years) with a further possibility of 25 per cent already surveyed districts being selected for saplings after eight years as per sampling procedure followed by the organization. The survey is based on the interpretation of photo-imagery recorded during October 2008 to March 2009. It records trees only over 10cm dbh class and when the harvesting of poplar in many locations is now being carried out at a young age as early as of four years. Many of the poplar trees thus get harvested even without getting a documentation in this report. These figures are just indicative numbers projected from limited information collected from limited sampled districts (178 districts from 2002 to 2009) and do not have much practical significance. The author, therefore, has been relying more on the interpretation of information collected on the nursery stock grown and that fresh planted in different locations. Most of this information is being regularly published for the benefit of others The information collected for the planting season 2011-12 from different locations is presented in the Table 5, which indicates that Uttar Pradesh is the leading state for growing 38.61per cent of total poplar in the country followed by Punjab (18.01 per cent), Uttarakhand (16.95 per cent), Haryana (16.33 per cent), Jammu and Kashmir (3.85 per cent), Himachal Pradesh (2.49 per cent) and other with collective share less than 5 per cent. A major share of poplar in Punjab is grown in compact blocks, whereas Jammu and Kashmir grows most of its poplar as shelterbelt around fields and orchards. The trend is mixed in most other states and is ever changing with change growers from year to year. These figures are again not absolute values on the status of surviving stems which undergoes a change every time, based on numerous factors.

Based on the above, published information and that collected from the field staff and personal contacts from different states, it is inferred that a total nursery stock grown in the country was 48 million, out of which around 25 per cent remain unsold especially from the low quality nurseries (WSD, 2011) (Table 6). Around 10 per cent stock is kept for multiplication for making next year nurseries. Further it is inferred that maximum poplar is planted on the farm land in association with agricultural crops and the share of poplar planted on forest land is very negligible. Like sapling production, there is also no database available for field planted poplar from most of the states.

Table 5. Estimated number of poplar saplings planted during 2011-12 planting season

State	Planted in block			Planted on boundary or row			Total	
	(No.)	Per cent of total	Per cent of state	(No.)	Per cent of total	Per cent of state	(No.)	Per cent of total
Jammu and Kashmir	100,000	0.56	8.33	1,100,000	8.17	91.67	1,200,000	3.85
Punjab	4,317,700	24.38	76.90	1,297,000	9.63	23.10	5,614,700	18.01
Haryana	2,635,000	14.88	51.77	2,455,000	18.23	48.23	5,090,000	16.33
Himachal Pradesh	430,000	2.43	55.48	345,000	2.56	44.52	775,000	2.49
Uttarakhand	2,625,000	14.82	49.67	2,660,000	19.75	50.33	5,285,000	16.95
Uttar Pradesh	7,253,800	40.96	60.26	4,784,500	35.53	39.74	12,038,300	38.61
Bihar	110,000	0.62	24.44	340,000	2.52	75.56	450,000	1.44
Rajasthan	115,000	0.65	51.11	110,000	0.82	48.89	225,000	0.72
Others	125,000	0.71	25.00	375,000	2.78	75.00	500,000	1.60
Total	**17,711,500**	**100.00**	**56.81**	**13,466,500**	**100.00**	**43.19**	**31,178,000**	**100.00**

Table 6. Estimated number of poplar saplings grown in nurseries and field during 2011-12

State	Nursery (No. in hundred thousand)			Field planting (No. in hundred thousand)		
	Government sector	Private sector	Total	Government sector	Private sector	Total
Jammu and Kashmir	4.00	9.00	13.00	0.00	12.00	12.00
Punjab	1.00	71.00	72.00	0.00	56.25	56.25
Haryana	20.00	114.00	134.00	0.00	5.00	51.00
Himachal Pradesh	1.00	8.00	9.00	1.00	6.75	7.75
Uttarakhand	2.00	90.00	92.00	2.00	51.00	53.00
Uttar Pradesh	1.00	150.00	151.00	0.00	120.00	121.00
Bihar	4.00	0.00	4.00	0.00	4.50	4.50
Others	1.00	3.50	4.50	0.50	5.00	5.50
Total	**34.00**	**445.50**	**479.50**	**3.50**	**260.50**	**311.00**

Nursery Production

Poplar is normally propagated by using hardwood stem cuttings collected from the last year nursery grown juvenile saplings. Stressed and desiccated cuttings or those collected from mature trees sprout late and cause variation in the nursery stock. Cuttings are planted in well prepared open nursery beds during January-February. With normal cultural operations of earth working, irrigation, weeding, and tending; saplings attain an average height of 3-6 m or sometimes more based on inputs and cultural operations provided to the nursery. Approximately 20,000 saplings are produced in an hectare nursery area. WIMCO now uses a different approach for growing saplings in its nurseries. The plantlets are first grown using reproduction means discussed above which are then planted in open beds any time till July depending upon the size of the saplings required in a particular locality (Dhiman and Gandhi, 2010). The saplings grown by the new means continue to grow sometimes till first week of November, remain in leaves till last week of December, lateral buds rarely sprout during the active growth period, have better diameter/ height ratio and looks fresh with soft bark compared to those planted by traditional stem cuttings route during January February. Terminal bud setting in traditionally grown saplings generally starts during the last week of October.

Plantation Establishment

Saplings are lifted during January and February, conditioned in fresh water for around 48 hours and are field planted after their nursery growth. The planting period is sometimes advanced to December and also extended to the first week of April depending on land preparation, occupation of fields with intercrops and other field conditions. The recent experimentation of planting poplar October onwards with certain innovations proved encouraging. Based on around half a dozen field trials across the RIPC, early planting of poplar saplings is now a reality and is being demonstrated to the farmers throughout the RIPC.

Poplar is planted inside and around agricultural fields. Land preparation near to poplar planting time, followed by one or two timely irrigation has a significant effect on initial survival of poplar. It is planted in augur made 7-10 cm round and 60-90 cm deep pits. Poplar develops major root system near the surface and the deep planting is followed for anchoring the trees against strong winds. On putting the sapling in the pit (hole), 3/4th of the pit is filled with top soil mixed with appropriate nutrient mixture that depends on the fertility of the soil. The fields are irrigated with surface water to an extent that some water stands inside pits which helps in settling the filled soil inside the pit. The remaining empty pit is filled after around a week with fresh soil and again irrigated for settling the soil. Irrigation, thereafter, is provided to agricultural crops till summers when additional irrigations are provided if intercrops are not grown along with poplar. Poplar is planted over a wide range of spacing and patterns. The most common spacing adapted are 5x5 m or 5x4 m or 7x3 m or 8x3 m in blocks and 2-3 m apart in lines and boundary plantations across the poplar growing region. Wider spacing favours growing agricultural crops with higher yields for longer period then closer spacing. Poplar grown in block plantations produces better quality timber with circular stem, less knots and other defects and therefore fetches higher price in the wood markets. Silviculturally, poplar grows better under mild competition in stands, whereas, trees tend to become branchier, if planted wide apart especially on boundaries. Experienced farmers who have grown it for 4-5 rotations by now still prefer to grow it in blocks for getting better returns and appreciation of their good quality timber value. Poplar timber from the state of PB still fetches relatively higher price in Yamunanagar (HR) poplar wood trading centre as most of it is grown in compact blocks in that state.

Poplar Based Agroforestry (PBA)

Growing intercrops is a normal practice and some aberrations of keeping fields without intercrops may occur occasionally. Crops grown in PBA are locality specific and originated through farmers innovations as these have been associated with their sustenance and life support system. Over 98 per cent poplar block plantations have been recorded to grow intercrops which vary with locality, age of trees, prevailing market conditions, season and economic conditions of the farmers (Dhiman, 2012). Farmers grow only those new crops which provide better returns compared to those traditionally grown by them (also see Chauhan *et al.* in this volume).

Plantation Management

Poplar is grown on agriculture fields and is a domesticated tree in India. It is grown on farm land with so many growth contributing variables in planting stock type, intercrops, cultural inputs, tending operations, insects and pathogens, climatic, edaphic and geological constituents that its productivity on any site is likely to vary with variation in any of these variables. The impact of these variables on poplar growth is easily exhibited in a very short span since the tree is very fast grown, and responds quickly to any of the management intervention. Higher timber productivity of 26.46 m^3 per hectare per year recorded for poplar on farm land

compared to just 13.65 m^3 per hectare per year on forest land (Singh and Jhajaria, 2001) justifies the importance of management inputs applied in the fields having both tree and intercrop culture together. Better growth of poplar obtained along water channels and poor growth in fields with top soil scraped and also on uncultivated fields indicate that even small changes in any of the growth variables has significant impact on the overall productivity of poplar. Variable silvicultural quality of the planting stock of same clone grown in different nurseries showing differential field survival and growth justifies the claim of higher sale price for its saplings by certain branded and established nursery growers. A good agriculturist has been proved a good tree grower since he better understands the needs of both intercrops and trees than most of the absentee land owners and casual growers due to their casual approach on poplar farming. Dhanda and Verma (1995) reported productivity of poplar grown with intercrops in PBA as 444.1 m^3 at years with MAI of 49.3 m^3 per ha per year and 292.0 m^3 at five years rotation with MAI of 58.4 m^3 per year and indicated the reasons for this variation in productivity due to harvesting age, management inputs and locations of fields along river beds or away on upland. The data on poplar farming available from other locations especially, Bihar (Dhiman, 2010b), Chhatishgarh (Puri *et al.*, 2002; Mishra *et al.*, 2004), and Maharashtra (Gogate and Deshpande, 1994) indicates lower growth and yield compared to that obtained in the RIPC. These warmer and drier sites are located at much lower latitudes than that of 28°N lower latitudinal limit for *P. deltoides* in its natural range in the USA and in its introduced locations in the RIPC. In addition, better agriculture production facilities and system in the RIPC encourages better growth of poplar and intercrops in this region.

Pruning poplar trees is an essential component of plantation management for improving the quality of timber and also to protect them from wind damage by reducing wind pressure on their crown. Wind damage to poplar is common throughout the RIPC. Generally, young trees of 1-2 years age get broken from the main stem, whereas, old trees get uprooted or bend with the wind pressure. In many locations, fields inundate with water for many days during rainy season forcing trees to bend or fall with gentle wind pressure. Two types of pruning are *in vogue*, namely lateral pruning and vertical pruning. The former is used to facilitate apical growth by lengthwise trimming lower side branches/ shoots just after planting and also to reduce wind pressure by reducing the crown size. Lateral pruning is again applied during tree dormancy stage in the following two winter seasons. Vertical pruning is used for improving the wood quality by selectively removing co-leaders and a few thick branches in the first and second year winter season and thereafter in alternate years to lift the crown to the stem thickness of around 30 cm girth since logs below this size are sold as firewood. In some locations, farmers have developed thumb rules to prune trees to the height near the transition of smooth bark to corky one. In lateral pruning, all lower branches are half cut, whereas, in case of vertical pruning thick branches are cut touching main stem with sharp tools. Lateral pruning is increasingly applied in wind prone areas, whereas, vertical pruning is applied throughout the RIPC. Anchoring trees with the support of ropes is a regular practice in many flood prone areas having heavy soils to save them from lodging with wind pressure. Young dislodged trees during rainy season are heavy pruned, erected and tied with ropes and many of them survive and grow till their final harvesting.

Poplar is normally harvested during pre- and post-winter cropping seasons in order to avoid damage to agricultural crops standing in the fields. For harvesting trees, the basal thick and side roots of the trees are exposed, cut with axes and the trees are made to fall on one side with their main root system (Fig. 1). Left over tree parts including roots are immediately cleared to make fields ready for growing next season crops including fresh poplar plantations. Of late, some farmers have started keeping their poplar fields free from agricultural crops during the harvesting year to take advantage of escalated wood prices during off-season harvesting season. Poplar trees grown on field boundaries sometimes felled without uprooting and many farmers now manage the coppice shoots arising from the stumps as a fresh crop. Like other trees, coppicing in *P. deltoides* also depends on age, season and clone type (Sharma *et al.*, 1996). Poplar harvested during monsoon or winter season coppices well, whereas, its capacity to give new shoots decreases significantly in hot and dry season. All stumps do not sprout and some gaps are created which the farmers try to fill with fresh planting or simply ignore gaps created after felling. As a result, the quality of wood produced from such coppice origin trees is poor because of high degree of branching, knots, and taper and it fetches low value in the market. The proportion of the coppice origin poplar is now increasing and constitutes a fairly significant component of poplar culture; i.e., approximately 5-8 per cent of total standing poplar in the RIPC (Fig. 2). The share of coppice origin poplar is more towards eastern limits of RIPC and also in some locations within this region where some casual poplar growers and those with low land holdings and poor economic conditions retain coppice shoots to avoid expenditure on making fresh plantations.

Rotation and Yields

Poplar is extremely fast grown and attain marketable size timber at very young age. It is generally harvested at six to eight years of rotation which sometimes is extended from four to twelve years. The tree is mainly grown as a cash crop for sale of timber to wood based industry. The main factors that determine the harvesting age of trees are the economical conditions of the grower, his immediate financial needs, market conditions, land holding size and his interest in agricultural crops. Farmers, in some locations where market for the under sized wood is now well developed, have started harvesting poplar at even four years of age to take early advantage of fluctuating wood prices in the market and also realize better value for cash intercrops like sugarcane which could be economically grown at the young age of trees. Farmers with good land holding size and better economic conditions prefer to harvest trees at old age and get better appreciation of the timber. Some farmers also postpone harvesting of trees to later age if the prices of wood are low in the market. Good growing plantations attains 5 m average height and 5 cm average diameter per annum with a ratio of around 100:1 for the first half of the rotation age of poplar growth. Current annual and mean annual increments culminate at a very young age in poplar (Fig. 4) in comparison to most other forest tree species. Current and mean height growth culminates faster in comparison to current and mean diameter growth. Dhanda and Verma (1995) reported that MAI of DBH is more for boundary trees (5.2-9 per annum) than in block plantations (3.8-7.8 cm per year).

Poplar logs of thick girth size are sold at higher prices throughout the RIPC. Percentage of logs with thick girth sizes increases with increase in the harvesting age of trees. A comparison of six plantations harvested at different ages from five years to 10.5 years during 2011 surrounding Bareilly location, Uttar Pradesh and monitored for log size-wise yield including that of firewood is given in Tables 7 and 8 (Fig. 3). The ratio of over (over 60 cm mid girth) and under size logs (between 50-60 cm mid girth) varies from 55 per cent in 5 years old trees to 95 per cent in 10.5 years old trees.

Marketing

Poplar logs are usually processed when these are fresh. The wood is harvested during the day hours, transported to the local wood markets or industrial units during the night and auctioned/sold in the early morning hours. Almost all components of poplar trees including logs, roots, lops and tops

Table 7. Timber volume (cmh-ub) in selected plantations with different harvesting ages

Location	Age (yrs)	Tree (no.)	Log. vol. (cmh-ub) for logs with mid girth		Ratio for mid girth logs	Timber vol./tree(cmh-ub)		
			(>60cm) (mid girth)	(<60 cm) (mid girth)	(<60/>60) (mid girth)	(>60cm) (mid girth)	(<60 cm) (mid girth)	Total
Atrauli, Aligarh, U.P.	8.5	2,880	1,534	82	94.93	0.533	0.028	0.561
Bhuta, Bareilly, U.P.	7	2,200	216	114	65.45	0.098	0.052	0.150
Shahajahpur, U.P.	6	630	62	30	67.39	0.098	0.048	0.146
Hardoi, U.P.	5	225	17	14	54.84	0.076	0.062	0.138
Bareilly, U.P.	5.5	170	16	8	66.67	0.094	0.047	0.141
Milak, Rampur, U.P.	10.5	150	82	4.5	94.80	0.547	0.030	0.577

Table 8. Total tree yield (by weight) in selected plantations with different harvesting ages

Location	Age (yrs)	Tree (no.)	Log weight in qtls				Weight in qtls	
			(>60cm) (mid girth)	(<60 cm) (mid girth)	30-50 cm (mid girth)	Firewood	Total	Per tree
Atrauli, Aligarh, U.P.	8.5	2,880	2.16	0.40	0.91	1.24	4.71	4.71
Bhuta, Bareilly, U.P.	7	2,200	1.53	0.81	0.80	1.00	4.15	4.15
Shahajahpur, U.P.	6	630	1.48	0.71	0.70	0.90	3.79	3.79
Hardoi, U.P.	5	225	1.16	0.96	0.71	0.87	3.69	3.69
Bareilly, U.P.	5.5	170	1.36	0.68	0.70	0.94	3.69	3.69
Milak, Rampur, U.P.	10.5	150	8.50	0.50	0.67	0.67	10.33	10.33

along with bark separated at processing sites or at harvesting sites are sold in the market. These are sold on weight basis which is recorded just before finalizing the deal for sale/purchase. Any delay in its sale results in weight loss due to loosing moisture and ultimately low value for the produce. The weight loss in logs is fast on thin logs and firewood than thick logs. Approximately 16.23 per cent overall weight loss was recorded in 35 days period from different components during the month of October (Dhiman, 2012). The growers therefore prefer to sell fresh wood on day to day basis. The wood is sold in around a dozen wood markets where rates for each thickness and quality grade (mainly based on knots and straightness) change on day to day basis. Yamunnagar in Haryana, Hoshiarpur in Punjab, Rampur and Hapur in Uttar Pradesh are the well established main markets for trading poplar wood and are also barometers for the poplar wood prices to local growers. Many wood based industrial units also make direct contacts with the poplar growers, purchase trees on lump-sum deals or weight basis and arrange their harvest and transport. The log grade is decided on its girth, namely over grade with girth thickness +60 cm, under grade with 50-60 cm girth thickness and 'sokta' with 30-50 cm girth thickness. The wood is also sold as a mixed lot of all tree components together and it attracts lower value than the graded lots. The thickness limits and their measurement points like thin, thick or mid end of logs have been changing over the years with ever changing demand and supply scenario of its wood in the local markets. These limits tighten during the period of surplus supplies and relaxed during the period of scarcity. Thick logs are usually used for peeling purpose and thin logs for making filling material for ply-board. Billets below this size, roots, lops and tops are sold as pulpwood and firewood. Wood is also traded on volume basis(cmh-ub) in forest corporations of a couple of hill states where some of it obtained from trees grown on government land is periodically auctioned from their wood depots around winters. Numerous traders have developed their business throughout the RIPC and farmers are at ease in selling most of their plantations on lump-sum basis to them. The entire operations and controls thereafter are arranged by the contractors. These contractors supply wood to main contractors operating from the main marketing centers which charge a percentage of commission from the sub contractors and supply wood to the industrial units on day to day basis. There is a lot of movement of poplar wood within and the RIPC (Fig. 4).

Economics

Poplar based agroforestry is reported to be economically viable and more profitable than many other land use options with minimum risks (Jain and Singh 1999, 2000; Dhillon *et al.*, 2001). Economical returns from poplar farming depends on a very large number of factors of which tree harvesting age, density and geometry of tree planting, land-use (forest or farm land), clone type, intercrops, plantation management, cultural inputs, market prices for input material and farm produce both of trees and intercrops at certain period of time are the major contributors. There have been numerous attempts from the very beginning of poplar culture on forest and farm land to estimate its economic viability. The economic viability of first large scale poplar plantation established over 20 ha forest land in 1966 and harvested in 1981 was reported to have 28 per cent internal rate of return and B:C ratio of 3.19 per cent at 13 per cent rate of interest (Chaturvedi, 1982a and b). The economic returns from poplar culture with and without intercrops were reported to vary with tree rotation (Mathur and Sharma 1983). For 8 years rotation, higher B:C ratio of 3.22 was reported for poplar culture on farm plantation with intercrops compared to 2.15 for forest plantation and with intercrops and 1.51 for forest land without intercrops (Mathur and Sharma, 1983), whereas, Dhillon *et al.* (2001) reported cost benefit ratio of 1: 1.92 and 1: 2.13 for pure poplar and for poplar and intercrops together. Cost benefit ratio on farm land at eight years rotation was reported as 1.86 and 1.70 for 12 per cent and 15 per cent discount rate of interest by including Rs. 5,000 as opportunity cost against a net loss due to agricultural crops (Chandra, 1986). Singh *et al.* (1988) reported that five year old poplar planted at 5x4 m spacing along with mentha intercrop under agroforestry gave net returns of Rs. 44,385 per ha through trees and Rs. 65,886 through crops. The single row plantation along with field bunds gave a net return of Rs. 11,067 per ha and Rs. 41,250 per ha over a period of three and seven years, respectively. Benefits from raising nursery stock are much higher (100.9 per cent) within one year (see Kiswan and Dinesh Kumar, [n.d.]).

The economical returns from poplar farming fluctuates with marketing conditions for sale of tree and intercrop yield components. There are daily, monthly, seasonal and annual variation in wood prices and these affect returns to poplar growers during the sale of their produce. Any change in the demand and supply system that even affect daily supply of the wood to the market affects its prices. The sale value of the wood from the plantations given in Table 8 based on the prevailing market rates during their sale time is given in Table 9. It is evident that the value of trees increases with age of harvesting, though the farmer has to incur some loss on loosing the yield of crops if trees are retained for long period.

PBA has already established benchmarks of high economical returns in agroforestry systems practiced in

Table 9. Economical returns (Rs. per tree) from selected plantations with different harvesting ages

Location	Age (yrs)	Tree (no.)	(>60cm) (mid girth)	(<60 cm) (mid girth)	30-50 cm (mid girth)	Fire-wood	Total value (per tree)
Atrauli, Aligarh, U.P.	8	2,880	1,728.33	237.29	365.83	148.88	2,480.33
Bhuta, Bareilly, U.P.	7	2,200	1,225.45	485.45	320.00	120.55	2,151.45
Shahajahpur, U.P.	6	630	1,180.95	428.57	280.00	108.00	1,997.52
Hardoi, U.P.	5	225	924.44	573.33	284.44	104.00	1,886.22
Bareilly, U.P.	5.5	170	1,091.76	409.41	280.00	112.94	1,894.12
Milak, Rampur, U.P.	10.5	150	6,800.00	300.00	266.67	80.00	7,446.67

India. Many of the average poplar growers are now realizing around Rs. one hundred thousand per acre per year (one US $=Rs. 53) net returns from PBA when its timber prices have touched all times high prices for over size logs as Rs. 1,100 per quintal in Yamunanagar, Haryana a poplar market. There is also a shift for harvesting poplar early at even four years age in some locations with the sole objective that growing of cash crops like sugarcane becomes uneconomical when the net returns per unit area and per unit time decreases after two harvests - the 2nd harvest being ratoon (coppice) origin. Appreciation of prices for even undersize poplar wood harvested at young stages is also motivating for this change.

Growers are getting a lump sum amount from the sale of poplar trees. Many growers believe that the income from the trees is net profitability from the PBA and the expenses from the beginning of poplar and intercrop culture in a rotation period are recovered from intercrop yields itself. Money received from the sale of poplar and intercrops being agriculture income is treated tax free and many growers have gainfully used it for diversifying their business activities and making assets.

Usage

Poplar wood is used for manufacturing around three dozen products (Dhiman, 2004). Poplar has now developed a complete use of its all tree components (Table 10). Even leaves and foliage with thin branches are lopped and converted into chips for sale to wood based industry as fire wood. Paper pulp is the third major use of poplar wood after panel industry and firewood in India (Fig 5). Fiber dimension, proximate chemical composition (Milea, 1980), and characteristics of lignin (Singh *et al.*, 1982) and hemicelluloses (Singh *et al.*,1982) in poplar wood make it one of the favored raw material for making paper of different grades, viz., wrapping /writing paper (Einspahr *et al.*, 1970), grease proof paper (Rai and Ilam Chand, 1988), and news print (Singh *et al.*,1981). Poplar is not grown exclusively for paper pulp and it is either the industrial wood waste or the left over material from plantations that is used as pulp wood. Most of poplar wood collected from sawmill waste, veneer waste, plywood trimming, and especially those parts which are not used either for sawing and peeling in poplar based industry are accepted raw material by the paper industry. From trees, only those rejected wood pieces with heavy defects like knots, bends, hollowness and those billets below 45 cm mid girth up to 30 cm mid girth or sometimes even less than that find use as raw material for paper and pulp industry. Poplar wood was exceptionally used for making paper by many paper industrial units within RIPC and as far as South India during 2003-05 when its prices were very low due to reduced demand on temporary closure of veneer industry.

Poplar protection

Two chapters, one each on insects and diseases are specifically devoted in this issue (see Ahmad and Faisal; Singh *et al.*). However, poplar being a very fast growing tree species is affected by numerous other biotic and abiotic agents (Table 11) of which the damage from wind, fire, insects, diseases, animals, and birds sometimes attain economical proportions.

However, there are numerous other biotic and abiotic agents which cause damage to poplar, some of which have been documented (Dhiman, 2011) and some others are identified separately through a diagnostic survey conducted among the progressive growers and its results reported here. A diagnostic survey was conducted among 178 progressive poplar growers and leading nursery

Table 10. Commercial and domestic use of poplar tree components

S. no.	Tree part	Use
1.	Leaves/foliage	Fodder, and firewood on chipping
2.	Bark	Firewood, and carrier for mosquito quails, etc.
3.	Branches	Firewood, pulpwood and timber
4.	Stem	Timber, firewood, and pulpwood
5.	Roots	Firewood, and timber

Evolving Business Models in Poplar Culture

Many farmers are now reporting lucrative returns from poplar nursery and plantation. Poplar culture, primarily in the private sector, is mainly driven by the economic considerations from the sale of nursery saplings to trees/wood. Besides the regular growers, poplar culture, over the last two decades, has evolved as business opportunity and a mean of self employment for numerous farmers and non-land owners. It is also an excellent opportunity to remain engaged in poplar related activities for remunerative returns. One such real case study indicating handsome net returns of Rs. one hundred thousand from 0.4 ha^{-1} yr^{-1} from PBA with cultivation of traditional sugarcane and wheat crops under poplar plantation is presented in this volume (Chaudhary and Chaudhary in this issue). There are numerous other growers with experience of even better returns with introduction of summer intercrops and even high value crops throughout the RIPC. There are numerous variants of business models in poplar nursery production, trading in saplings, plantation production and maintenance, wood trade including outsourcing in all these activities. Business models with variations exist in nursery production both on private land and hired land such as selling the entire nursery on hectare basis on lump-sum deals much in advance of lifting the saplings, their delivery on negotiated price without and with support in getting them planted on farmer's land by both the nursery growers and service providers with variable earnings from commissions or margins. Many nursery growers and traders are trying to reach the growers and markets to make their business models financially lucrative. For example, large scale selling outlets are created during planting season on the road heads at number of locations across the RIPC. A couple of cases have also recently emerged in Uttar Pradesh. where some absentee landlords and even some businessmen have taken up poplar plantations through service providers with the condition that the saplings to be used for planting on their fields are procured from the branded nurseries and the payment is released only on presentation of receipts of sapling purchase and also when the service provider has ensured expected final survival of planted saplings. The margin money for the service provider in this case is higher but the growers are happy in ensuring better survival and expected returns from their plantations. Similar variants also exist in growing poplar plantations which are grown on hired lands for different years with variable terms and conditions. One such real case is summarized below (Dhiman, 2012).

Mr. R. Singh took up poplar plantation as a business on leased land from one of his old known farmer in Pilibhit District in U.P. during 2004 when poplar prices were very low in the market. He entered an unwritten understanding with the farmer that the former will pay Rs. 15,000 from 0.4 ha^{-1} yr^{-1} for seven years to the latter during the beginning of each year. Mr. Singh planted 500 saplings of WSL 22 at 4.5m x 4.5m spacing in February, 2004 and finally harvested 95 per cent of the trees, in April 2011. Farmer took up sugarcane in the first two years and wheat, thereafter, till sixth year as intercrops at his own costs. Mr. Singh pruned the poplar trees during the second, fourth, and fifth years as practiced in the area. There was no cost involved in pruning and the labourers got the pruned branches as fuelwood free of cost. Mr. Singh spent Rs. 8,000 on cost of saplings and Rs. 1,500 on its planting during the first year. The cumulated cost when compounded to 7 per cent inflation was Rs. 26,215, Rs. 44,100, Rs. 63,237, Rs. 83,714, Rs. 105,624, Rs. 120,624, Rs. 129,067 and Rs. 154,152 at the end of year 1, 2, 3, 4, 5, 6 and 7 respectively. Total cost of production on 2 acre poplar plantation compounded with 7 per cent inflation was Rs. 271,552 that also includes an expenditure of Rs. 117,400 on harvesting of trees. The sale proceed from timber, roots and firewood was Rs. 1,150,472 from 0.8 hectare giving him a net profit of Rs. 878,920 in seven years and Rs. 62,780 from 0.4 ha^{-1} yr^{-1} with provision of 7 per cent inflation. The cost-benefit ratio is calculated as 1:3.24 with- and 1:3.40 without- considering 7 per cent inflation.

Similar variants with some modifications of understanding and arrangement for growing poplar as business opportunity exists in different parts of the RIPC. One landless entrepreneur in Udham Singh Nagar, Uttarakhand has been regularly growing poplar on leased land for over a decade period now. He is taking land on lease for 6-7 years, making and maintaining poplar plantation himself but subletting intercropping to other growers at some lease amount. Presently, he is earning Rs. 3,000 from 0.4 ha^{-1} $month^{-1}$ as income. He is having number of plantations under this arrangement. The present poplar wood prices are in the upper band and fluctuate periodically, seasonally, and daily. Some experienced entrepreneurs' have now learnt the trick of the trade to take up the lands on hire when poplar wood prices are low in the market and many of the growers restrain from planting at that stage.

Table 11. Major causes of damages to poplar

S. no.	Cause	Agents causing	
		Major damage	Minor damage
1.	Abiotic agents	Wind, fire, floods, hails	Sun scorch, high temperature
2.	Animals and birds	Blue bull, monkeys	Rabbits, rats, pigeons, crows, wild bores, porcupines.
3.	Insects	*Clostera* species, red mite, termites, shoot borer, leaf sap sucking insects, mango mealybug	Leaf miner, bark borer, stem borer, san jose scale and others
4.	Pathogens	Fungi causing leaf blight, blistering, set rot; damping off to seedlings; MLOs causing flattening	Fungi causing leaf spots, cutting rot, bacteria causing canker
5.	Physiological	Zn and S deficiency, moisture stress	Bark burst
6.	Human beings	Physical damage during cultural operations	Thefts
7.	Parasites	Mistletoe, *Cuscuta* spp.	*Ipomea* sp.

Table 12. Biotic and abiotic agents causing damage to poplar

Biotic and Abiotic agent	State				
	Punjab	Haryana	Uttar Pradesh	Uttarakhand	Overall
Wind storms	1	2	1	2	1
Water stress (both excess and deficit)	2	1	2	1	2
Blue bull	14	3	3	6	3
Termites	3	4	4	3	4
Shoot/stem borers	8	6	6	4	5
Theft and damage for revenge	16	10	5	9	6
Clostera spp. (poplar leaf defoliator)	7	7	8	5	7
Fire	6	5	7	12	8
Root rot	4	8	9	7	9
Monkeys	12	21	10	8	10
Zinc deficiency	5	9	11	15	11
Leaf spots	10	23	12	14	12
Sap suckers including red mite	18	22	14	11	13
Mealybug	15	16	17	13	14
Hails damage	9	13	13	18	15
Flattening	23	12	18	10	16
Sulfur deficiency	11	19	15	17	17
Domestic animals	24	17	16	20	18
Leaf miner	17	11	19	16	19
Blistering	19	24	20	19	20
Poplar fever	20	22	21	22	21
Others	25	18	22	21	22
Rats	22	21	23	23	23
Parrots	13	20	24	24	24
Crows	21	25	25	25	25

growers in four states, viz., Punjab, Haryana, Uttarakhand, Uttar Pradesh, and throughout the RIPC to identify the agents responsible for damages to poplar as perceived by the growers. Response was obtained on a format having listing of 25 biotic and abiotic agents (Table 12) and the respondent were requested to enlist them in the order of their potential to cause damage to poplar nurseries and plantations. The overall rank of the agent was calculated to two decimal points and the serial number as given in the table was decided based on its absolute value. It revealed that abiotic agents like wind, water stress (both excess and deficit) leads the table in term of their potential to cause damage. During discussions with many of the growers, the identification of damages and causal agents for disease was extremely difficult for them and they tried to group them in order of their field observations than scientific terminology. The potential of some agents like bull is very high in Uttar Pradesh and Haryana, but very low in Punjab and little in Uttrakhand. Besides these agents poplar wood is also subjected to attack and degradation during storage in log yards and depots. This damage was restricted to some specific locations and factories and was included in the survey.



Fig. 1. Tree harvesting operation includes felling trees along with main root system.



Fig. 2. A third rotation coppice variable growth of poplar trees retained on field boundaries along a roadside in Rudrapur, U.S. Nagar, Uttrakhand.

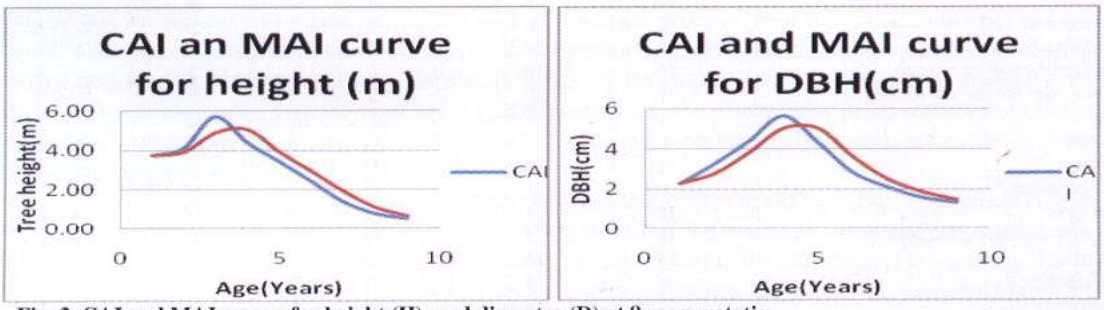


Fig. 3. CAI and MAI curves for height (H), and diameter (D) at 8 years rotatio

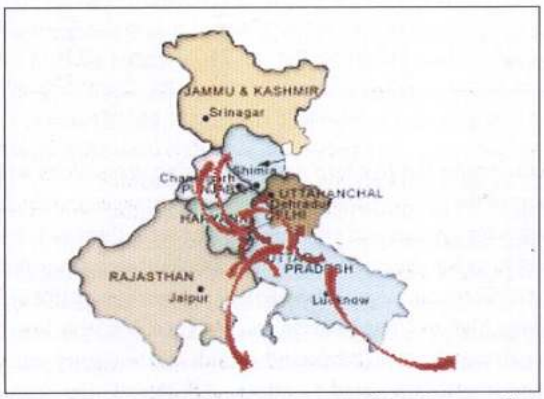


Fig. 4. Red arrows show movement of poplar wood to other states



Fig. 5. Peeling waste from veneer industry for pulpwood in the RIPC.

Conclusion

Firmly established poplar culture with introduced germplasm of *P. deltoides* is a source of numerous goods and services at local, regional, national and global level. Poplar culture is largely in the private sector and immensely helping the country in mitigating chronicle shortage of wood raw material for domestic and industrial use. The unique success of establishing poplar culture on farm land with active participation of numerous growers is path breaking for initiating similar programmes under synergic partnerships between industry and farmers. Poplar is grown as a cash crop and providing remunerative returns to its growers, generating employment in rural areas, raw material for wood based industry, revenue through taxations for the state governments, increased tree cover to meet the objectives of the National Forest Policy 1988 and rehabilitation of river banks for their protection and averting soil erosion. With increasing demand for its wood, poplar culture is likely to expand within the RIPC and also to new locations in northeastern states along the Himalayan range for the benefit of the people and the country.

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