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Important insect pests of poplars in agroforestry and strategies for their management in northwestern India

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Abstract

Today, more than 143 species of insects infest both indigenous as well as exotic species of poplars in northwestern India, with about 65 species infesting *Populus deltoides* alone. Random sampling surveys (1984-2002) were undertaken in lower hills and plains of six states (Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, and Jammu and Kashmir) in this region. The survey included 36 nurseries, 84 large ($\geq$ 3 ha) and 255 small ($<$ 3 ha) block and bund plantations and recorded seven species causing outbreaks. However, eight insects having wide spread distribution in this region were identified as posing a threat to agroforestry with *P. deltoides* and need to be managed. Amongst these, three species (*Clostera cupreata, C. fulgurita* and *Apriona cinerea*) were ranked as 'major pests' as they had relatively higher incidence ($>$ 50% of attack) and caused extensive economic loss during outbreaks, coupled with tree mortality which persisted for several years in succession over large areas. Five insects were identified as 'potential pests', as they also caused heavy infestation and economic loss, but only in some years, on a localized scale and with no large scale plant mortality, but need to be checked to improve productivity. The 'potential pests' were: one species in plantations (*Ascotis selenaria*) and four insects in nurseries [(*Eucosma glaciata* , *Phalantha phalantha, Nodostoma waterhousie* and white grubs) with $>$50% incidence]. Integrated pest management practices, comprising cultural methods, use of bio-pesticides, tolerant poplar varieties/clones, natural enemies, recommended safe insecticides and avoiding alternate host plants of the pest, are discussed for important pests.

Introduction

Introduction of exotic fast growing poplars in northwestern India (above 28° N) started as far back as 1950 (Mathur and Sharma 1983). This was done to cope with the commercial demand for timber as indigenous poplars to India, namely *Populus ciliata* Wall. Ex Royale, *P. gamblei* Dode, *P. jacquemontiana* Dode var *glauca* (Haines), *P. alba* Linn., *P. nigra* Linn. and *P. euphratica* Oliv., could not gain commercial importance in agroforestry in this region on account of their poor adaptability (Tiwari 1993) and relatively slower growth. Thereafter, various exotic fast growing poplars were introduced from Europe and North America in the early 1960s and 1970s and their trial plantations were raised by Uttar Pradesh State Silviculturist in the central Tarai region (Chaturvedi 1981). These trials demonstrated that some of the species and clones showed great promise: faster growing, producing good timber and compatible with agricultural crops. Cottonwood, *Populus deltoides* Bartr. Ex Marsh, a poplar species from Mississippi delta of U.S.A., proved to be best suited for the plains of northwestern India. Amongst the

various clones tested, clones G-3, G-48, D-121 were found most productive (Chaturvedi 1981) and their cultivation was started on a large scale. The demonstration effect of these plantations boosted the cultivation of *P. deltoides* amongst farmers of the area. During the 1980s and 1990s, *P. deltoides* has been extensively planted commercially under agroforestry by farmers of northwestern India (Chandra 2001) owing to its fast growth [short rotation time of 5-8 years (Chaturvedi and Rawat 1994)], high productivity [> 30 m^3 ha^{-1} $annum^{-1}$ (Chandra 2001)], winter deciduous nature (FAO 1979) and inter-cropping with a wide range of arable, vegetable, spice, and fodder crops (Newman 1997). Over 11 million trees of *P. deltoides* [mainly clones G-3, G-48 (Australian), D-121, D-67, S_7C_8, S_7C_{15} and S_7C_{20} (American)] were planted from 1979 to 1991 alone in Punjab, Haryana, Uttar Pradesh and Uttaranchal states, covering an area of 22,000 ha under a partnership scheme between a private match producing company, WIMCO Ltd., farmers and financial institutions (Piare Lal and Lal 1991; AFC 1993). Later, until 1995, these plantations had been estimated to cover an area of 40,000 ha (Newman 1997) extending into Himachal Pradesh and Jammu and Kashmir (Jammu region) states. The area planted with poplar during the 8th 'five year economic plan of India' (1992-1997) in these states was ca. 23,000 ha/year and poplar still is an important cash crop (Chandra 2001). An estimated 30 million trees covering 0.06 million ha land is today under pure poplar cultivation in northwestern India with an average density of 500 trees/ha as an 8-year rotation crop, producing 1.125 million m^3 industrial wood annually which meets 5 percent of the countries total needs (Chandra 2001). This figure is expected to reach 0.16 million ha by the next 5 years (Chandra 2001). Today, *P. deltoides* is cultivated in boundary plantings, blocks and rows of trees in cropped areas and also intercropped with annual crops throughout this region above 28° N latitude (Figure 1). Its timber has multipurpose uses: matchwood, plywood, particle boards, cardboard, crates, pulp, packing material, pallets, furniture, planks, fuel wood, etc. The average annual net returns for poplar in Haryana state were Rs. 54,753/ha/year (as pure crop) and Rs. 72,480/ha/year (with intercropping) at 12% discount rate over seven year rotation. The benefit: cost ratios in the above two planting situations were 1.92:1 and 2.13:1, respectively (Dhillon et al. 2001).

Insect pest problem in exotic poplars

Large scale defoliation of *P. deltoides* trial plantations (clones G-3,G-48,IC $-$ 100, 3-4 years of age) by *Clostera cupreata* (Butler) and *C. fulgurita* (Walker) (poplar defoliators) were reported from time to time from the central Tarai region of Uttar Pradesh (Seth 1969; Lohani 1976; Chaturvedi 1981; Singh et al. 1983). By the 1980s the defoliation outbreak spread over an area of 1100 ha, became alarming and was suppressed by aerial spraying of carbaryl (sevin) insecticide (Singh et. al. 1983; Singh 1988). This defoliator has now spread through out the distributional range of *P. deltoides* in northwestern India. An attack ($> 25\%$ tree defoliation) by *Clostera* spp. is known to significantly decrease the growth increment of poplar trees (Gao et al. 1985). Also, artificial defoliation ($\geq 75\%$) is known to significantly decrease the total bio-mass of poplar trees by an average of 33% (Reinhenbacker et al. 1996). Complete loss of leaves and defoliation late in the growing season, for instance in August, are generally the most damaging because they leave the plant in a weakened condition and open to attack by other pests and diseases. Severe and repeated defoliation in young plants by this pest results in their mortality (FAO 1979 and Singh and Singh 1986).

High (88%) incidence of attack by another pest, *Apriona cinerea* Chevrolat (poplar stem borer), was reported in two-three year old *P. deltoides* plantations, from Paonta valley in Himachal Pradesh state (Verma and Khurana; 1985); 34% incidence from Jammu region (Sharma and Bhatia; 1996) and also from other parts (Uttar Pradesh and Haryana) in the region (Singh et al. 1987). An attack by this borer into the tree bole renders its timber unsuitable for any commercial use, as the entry of fungus and pathogens in the bored galleries causes discoloration of its wood and its becomes weak, offering little resistance to wind and gets broken by a modest gust. Repeated attacks result in forking of the bole or tree mortality (Singh and Prasad 1985).

Previous studies on insect pest of poplars in the region

Mathur and Singh (1960) were the first to list 42 insect species, mostly indigenous to India and adjacent countries, that caused damage to poplar and its timber in India. Singh and Singh (1975) later listed 17

species as important pests of poplars in developing countries, including India. Sen-Sarma and Gupta (1979) have also discussed 33 poplar pests highlighting the importance of *Apriona cinerea* Chevrolat, *Clostera cupreata* and *C. fulgurita* in causing major problems. Rishi (1979) also identified 32 insect pests from Kashmir valley pointing out that *Lymantria obfuscata* (Indian Gypsy moth-defoliator) and *Aeolesthes sarta* (Quetta Borer- a xylophagous insect) as serious pests of hill poplars. Verma et al. (1980) reported 55 insects [Lepidoptera (16); Coleoptera (13); Hemiptera (13); Isoptera (4), and nine species of some other orders] feeding on poplars in Himachal Pradesh along with information on their nature, extent of damage and control measures. According to Verma et al. (1980) none of the earlier reported insects on poplar had attained pest status in Himachal Pradesh but considered 16 species to be major or minor pests in various parts of India based on earlier reports published by Rishi (1979), Rawat (1979) and Sen-Sarma and Gupta (1981). A booklet published by Singh and Singh (1986) identified 16 insects [*Malasoma populi*, *Plagiodera versicolora*, *Clostera cupreata*, *C.fulgurita*, *Malacosoma indica*, *Lymantria obfuscata*, *Neocerura wisei*, *Euproctis signata*, *Pyrausta diniaslis*, *Eucosma glaciata*, *Apriona cinerea*, *Aeolesthes sarta, Macrotoma crenata*, *Quadraspidiotus perniciosus*, *Pemphigus* spp. and white grubs], as poplar pests important from economic point of view in nurseries, plantations and natural stands in this region. Besides, Singh and Singh (1986) also gave brief information on their distribution, life-cycle, nature of damage and control measures. From Punjab state, Sohi and Mann (1986) had reported a species of leaf hopper, *Kusala salicis* (Cicadelidae) as a new pest of poplars. Sohi et al. (1987) had also identified poplar hairy caterpillar, *Clostera restitura* as a major defoliator of poplar in Punjab. Later, Sohi (1989) had listed 26 insects feeding on poplars from northwestern India of which according to him five species, defoliators, *Clostera restitura* Walker and *C. fulgurita* Walker, along with leaf hopper *Kusala salicis* Ahmad, an unidentified leaf webber and a blotch leaf miner, were becoming major limiting factors for poplar cultivation in Punjab. Singh (1991) had reported a polyphagous defoliator *Orgyia postica* as new species attacking *P. deltoides* in Uttaranchal. Tiwari (1993) had compiled as list of 108 insect species [defoliators (58), stem and shoot borers (23) and sap suckers (27)], as pests of poplars in India giving information on life history and control for half of them. Chandel and Verma (1998) worked on the bionomics of large poplar leaf beetle, *Chrysomela populi* found in the hills. Thakur (1999) had reported the insect pest status of poplars in India by compiling a list of 120 insects species comprising mainly of cockchafers (7), defoliators (58), stem and shoot borers (23), sap-suckers (27) and termites (4). Most recently, Ahmad et al. (2001) also had complied a systematic list of 132 insect species feeding on poplars in India and Pakistan, based on published literature.

Present scenario: Insects of P. deltoides under agroforestry

Random sampling surveys were conducted from 1984–2002 in all the *P. deltoides* growing areas under agroforestry in lower hills and plains of six states: Uttar Pradesh, Uttaranchal, Haryana, Himachal Pradesh, Punjab and Jammu and Kashmir (Jammu), of north–western India. These surveys lasted more than 350 days covering 36 nurseries and 84 large ($\geq$ 3 ha) and 255 small ($<$ 3 ha), both block and bund plantations of *P. deltoides*, during all the seasons. Forty-one insect species were recorded feeding on *P. deltoides*, with only seven species causing heavy damage or outbreaks to poplar plantations and nurseries (Table 1).

However, eight insects (*Clostera cupreata, C. fulgurita, Apriona cinerea*, *Acostis seleneria, Eucosma glaciata, Phalantha phalantha, Nodostoma waterhousie* and white grubs) were identified as important pests (Table 2), based on the following characteristics.

Three species (*Clostera cupreata, C. fulgurita* and *Apriona cinerea*) were ranked as 'major pests' of *P. deltoides* in northwestern India as they had: (1) wide spread distribution (i.e., in at least 5 out of the 6 states practicing agroforestry with *P. deltoides* in northwestern India, (2) caused significant or even complete growth loss to plantations (i) over large areas, (ii) for years in succession, that had lead to (iii) large scale tree mortality and (3) had high incidence/occurrence in more than 50% of the total samplings carried out during the entire study period in the region [when a plantation or a nursery is taken as 1 unit, the presence of an insect species was determined on a scale of 1-375 (36 nurseries + 84 big plantations + 255 small plantations, combined, that were sampled)]. An attack by these species reduces the timber quality and/or causes extensive economic loss and are hence of primary importance and priority for management.

Table 1. Out breaks of insects recorded during the survey (1984-2002) on Populus deltoides in northwestern India.

Sl. no.	Insect species	Location (State)	Month	Year	Age of trees	Affected area	Appearance of infested plants	% incidence & (Impact)
1&2	*Clostera fulgurita* & *C. cupreata*	Central Tarai Region (UT)	August–Sept.	1984	7-8 years	> 1000 ha (bund & block plantations)	Leafless crown and dead plants	100 (loss in growth and tree mortality)
		Allawalpur, Chutmalpur (UP)	June–October	1990	4 years	< 400 ha (block)	Drying of crown	100 (loss in growth)
3	*Eucosma glaciata*	Shilly , Poanta , Solan (HP)	June–July	1993	(nurseries)	1 ha	Dying of shoot tips resulting in forking of leader shoots	80 (loss of straight bole/timber shape)
4	*Apriona cinerea*	R.S.Pura, Jammu (J&K)	March–April	1987–88	2 years	5 ha (block plantation)	Drying of entire plants	> 60 (tree mortality)
5	*Nodostoma waterhousie*	FRI, Dehra Dun (UT)	March–April	1992–1993	(nurseries)	4 ha	Drying of tops	100 (loss in growth)
6	*Ascostis selenaria*	Rudrapur (UT)	April–May	2002	7-8 years	200–300 ha (block plantation)	Leafless crown	100 (loss in growth)

*North-west Indian States: J & K-Jammu & Kashmir ; HP-Himachal Pradesh ; UT-Uttranchal ; UP – Uttar Pradesh.

While five insects were identified as 'potential pests' as they had: (a) wide spread distribution (i.e., in at least five out of the six states practicing agroforestry with *P. deltoides*, (b) caused growth loss to trees during heavy infestations but only (i) locally, (ii) during some years but not in succession and (iii) did not cause large scale plant mortality. These species need to be monitored annually for their abundance status and distribution range/change and checked locally for improving productivity.

Amongst the 'potential pests', a looper defoliator, *Acostis seleneria* Hubner had established in poplar plantations (2002) in the absence of *Clostera* spp. in Rudrapur, Udham Singh Nagar District of Uttaranchal state. Only 11% incidence by this pest was recorded in northwestern India during the survey.

In the nurseries, four insects are potential pests as they caused extensive damage to the cuttings and ETP's and also had high incidence of attack (> 50% samplings). These were: (i) a shoot borer moth *Eucosma glaciata* and (ii) the leopard butterfly, *Phalantha phalantha* (Table 1). Both the species feed on the tender tips of leader shoots that results in stag headedness in nurseries and young plantations all over the lower hills and adjoining plains of Himachal Pradesh and Uttar Pradesh states (Singh et al. 1995; Singh 1996). (iii) the poplar leaf beetle, *Nodostoma waterhousie* Jacoby also extensively feeds (April–September) on the foliage thereby causing it to turn entirely brown by the end of September (Singh and Singh 1995), resulting in growth loss. (iv) Several species of white grubs (Table 2) have also been reported to damage poplar cuttings raised in nursery stools in Himachal Pradesh (Singh and Singh 1986) and Uttaranchal.

In addition, two species of termites, *Copotermis heimi* Wasmann and *Odontotermis distans* Holmgren (Table 2) are also worth mentioning, as they also cause small scale mortality by die back/drying of stems of poplar in nurseries and plantations during summer in Uttar Pradesh and Uttaranchal states (Thakur 1978 and 1999), but their incidence was small (4%) during the present survey).

Integrated pest management

It has now become necessary to manage important pests and to keep their populations below economic injury levels under agroforestry with *P. deltoides*. Chemical control of poplar insects using insecticides such as BHC, DDT, lindane, chlordane, aldrin, bid-

Table 2. Distribution, nature of damage, infestation period and potential impact of important pests of *P. deltoides* in northwestern India.

Sl. no.	*Insects*	Alternate/collateral host plants in north-west India	Areas of prevalence (states)	Nature of damage	Period of infestation (no. of gen/year)	Symptoms and potential impact
A. Plantation pests						
1&2.	Poplar defoliators – *Clostera cupreata* Butler & *Clostera fulgurita* Walker (Lepidoptera: Notodontidae)	*P. alba*, *P. nigra*, (*Salix alba*, *S. babylonica tetrasperma*, *Xylosma longifolium*, *Cassine glauca*, *Elaeodendron glaucum*, *Gymnosporia falconeri* – alternate winter hosts)	J&K,HP,HR,UT,UP	Larvae are defoliator	March–November (8-9)	Tree mortality due to rapid infestation and deformities in the bole; loss in growth
3.	Looper – *Ascostis selenaria* Hubner (Lepidoptera: Geometridae)	*P. casale*, *P. robusta*, (*Acacia farnesiana*, *Albizzia procera*, *Cannabis sativa*, *Dalbergia sissoo*, *Melia azadirach*, *Phoebe lanceolata*, *Vitex negundo*, *Shorea robusta*, *Mallotus philippenensis*, *Murraya koenigii*, *Ricinus cummunis*)	J&K,HP,PB	Larvae are defoliator	April–November (5-6)	Loss in growth increment due to repeated defoliation
4.	Poplar stem borer – *Apriona cinerea* Chevrolat (Coleoptera: Cerambycidae)	*P. casale*, *P. eugenii x euramericana*, *P. robusta*, *P. regenerata*, *P. generosa*, *P. nigra*, *P. nigratricarp*, *P. yunnanensis*; (*Morus* spp., *Prunus* spp., *Pyrus* spp., *Ficus* spp.)	J&K,HP,UT,UP,PB,UT,UP	Larvae borer of xylem in stems, trunk, roots of standing trees.	July–November (bi-annual)	Drying of branches and later the entire stem leading to tree mortality mostly in young trees – infestation renders the bole/timber useless for commercial use
B. Nursery Pests						
5.	Poplar Shoot Borer – *Eucosma glaciata* Meyrick (Lepidoptera: Tortricidae)	*P. ciliata*, *P. yunnanensis*	HP,UT,UP,J&K	Larvae borer of green shoots leading to drying of shoot tips	June–October (2)	Forking to leader shoots results in branching and crown formation with small and stunted bole – loss of timber quality
6.	*Leopard Butterfly* – *Phalantha phalantha* (Lepidoptera: Nymphalidae)	*P. casale*, *P. robusta*; (*Xylosma longifolium*, *Salix tetrasperma*)	HP,UT,UP,HP,J&K	Larvae defoliator of leader shoots and young leaves	July–September (2-3)	Loss in growth increment
7.	Poplar leaf Beetle – *Nodostoma waterhousie* Jacoby (Coleoptera: Chrysomelidae)	*P. casale,P. ciliata, P. nigra, P. robusta, P. yunnanensis;* (*Salix tetrasperma*)	J&K,HP,UT,UP,PB	Larvae and beetle both defoliate	April–June (2)	Loss in growth increment due to continuous and repeated infestation
8.	White grubs – *Holotrichia* sp., *Granida* spp., *Brhamina* sp. (Coleoptera: Scarabaeidae)	All species of poplars and other broad leaved nursery grown plants	J&K,HP,UT,UP,PB	Beetle feeds on the leaves while the grub debarks and cuts the roots of cuttings and young plants	April–September	Drying of young plants – plant mortality
C. Termites						
9.	*Coptotermis heimi* Wasmann (Isoptera: Rhinotermitidae)	–	UT	Girdles root/shoot of cuttings and heart wood of plants up to 3 m above the ground	June–September	Die back of stems – tree mortality
10	*Odontotermis distans* Holmgren (Isoptera: Termitidae)	*P. casale*	UT,UP	Attacks heart wood from the ground or through injuries in the stem near the ground	June–September	Drying of stems – tree mortality

*North-west States: J&K – Jammu & Kashmir; HP – Himachal Pradesh; UT – Uttaranchal; UP – Uttar Pradesh; PB – Punjab and HR – Haryana.

rin, parathion, lead arsenate, etc., in the 1970s and 1980s, as recommended by earlier authors (Thakur 1978; Rishi 1981; Sen-Sarma and Gupta 1981; Singh and Singh 1986; Singh 1988; Sohi et al. 1987, 1989, etc.) is no longer safe. These insecticides are now banned due to their high toxicity, longer persistence in the environment and deletirious effect on beneficial insects and other non-target organisms including human beings.

Hence, new control measures are required to be worked out. Integrated pest management options, recommended now for economically important poplar pests of northwestern India today, are given below.

Xylophagus insects/Borers

Stem borer, Apriona cinerea. Prune and burn all the attacked branches during September–October to kill the grubs before they enter the main stem (Singh and Singh 1986). Badly infested plants of one to three years of age, infested trees that break off due to gusts of wind, infested material remaining after a harvest and dead stumps of poplar, should be destroyed by burning to prevent re-infestation in the next rotation stands. These places become favourable breeding ground as well as loci for the spread of the borer. New plantations should also not be established near infested stands. Alternative/collateral hosts of the borer (Table 2) must be removed from areas adjoining poplar plantations. *P. deltoides* clone G-3 has now become susceptible to this pest and should be avoided in infestation prone areas. Insecticides may be used in heavily infested areas and should be applied to the main stem during winters or just before when the adults emerge, in early spring. Fumigating the main stem kills the grub. Inject 5 ml fumigant (saturated solution of para-di-chloro-benzene in kerosene oil or carbon disulphide) using a syringe in lowest ejection hole made by the grub in the bole and then plug the holes with moist clay (Singh and Singh 1986). Or else spray a systematic insecticide such as methyl demeton or phosphamidon (0.01–0.02%) during August–September (Verma et al. 1983; Singh and Verma 1998).

Shoot borer, Eucosma glaciata. Prune and burn off the affected branches. Foliar spray of dimethoate (0.02–0.04%) in May–June and then again in August–September on the shoots can be applied. Monthly soil application of aldicarbe (20-40 g/m^2) or carbofuran (3G) at the rate of 10 g/m^2 (Singh 1986; Kapoor et al. 1994; Singh 1996) from April to September is also effective against this pest.

Defoliators

Poplar defoliators [Clostera cupreata, C. fulgurita, C. restitura and (Common Leopard Butterfly *Phalantha phalantha*)].

The most extensively planted *P. deltoides* (G-3 and G-48) clones in northern India have now become susceptible to *Clostera* spp. due to their narrow genetic base. Hence, these clones should now be replaced by new tolerant clones (Table 3) having same or more productivity and may be selected for plantation in defoliator prone areas (Singh 2000; Singh and Pandey 2002). A genus specific Nuclear Polyhedrosis Virus (NPV), a *Baculovirus* of subgroup A, infects and kills *Clostera fulgurita* populations in large number in field plantations of poplar particularly during the rainy season (this disease is characterized by colour change and rapid disintegration of the later instar larvae with water oozing out of their body. Cadavers hang upside down in plantations. The number of polyhedral inclusion bodies (PIBs) per larvae range from 0.37×10^9 to 2.92×10^9). Artificial infection of the disease to the healthy larvae has been achieved by feeding the larvae of *Clostera fulgurita* and *C. cupreata* together on poplar leaves sprayed with a crude suspension of NPV in the laboratory (42.66 per cent larval mortality recorded in the laboratory by this method). Cross infectivity tests also confirms the host specificity of the pathogen (Ahmad and Sen-Sarma 1983; Sen-Sarma and Ahmad 1984). Recent studies have shown that three indigenous egg parasitoids [*Trichogramma poliae* and *T. chilonis* (Hymenoptera: Trichogrammidae) and *Telenomus colemani* (Hymenoptera: Scelionidae) (Sen-Sarma and Gupta 1981; Ahmad 1992; Ahmad et al. 1997; Ahmad et al. 1999 and 2002)] are promising against *C. cupreata*, as they are (i) relatively common in the poplar plantations compared other species of egg parasitoids, (ii) can be mass reared easily in the laboratory through out the year on *Clostera* spp. and other alternate host insects (e.g., grain moth, *Corcyra cephalonica*), (iii) released in mass and (iv) are able to establish themselves in the field on *Clostera* spp. during heavy infestations thus suppressing its population. Besides, some predators (Table 3) also check *Clostera* spp. population in the field. Amongst these, a predatory bug, *Canthecona furcellata* Wolff (Pen-

Table 3. Natural enemies and tolerant clones worked out against some important insect pests of poplars

Sl.no.*Insects*	Natural enemies	Tolerant cultivars/provenances/clones of poplar
A. Plantation pests		
1&2. Poplar defoliators – *Clostera cupreata* Butler & *Clostera fulgurita* Walker (Lepidoptera: Notodontidae)	a. Predator – *Canthecona furcellata* (Pentatomidae) (4), *Sycanus collaris* (Reduviidae) (3), *Callicida splendidula* (Carabadae);b. Parasitoid – Egg: *Telonemus colemani* ,*Trissolocus* sp. (Scelionidae), *Trichogramma chilonis*, *T. poliae*, *T. perkensi*, *T. acheae*, *T. pretiosum*, *T. exiguum* (Trichogrammidae), *Ooencyrtus lucina* (Encyrtidae), *Pediobius* sp. (Euplophidae), Larval: *Aleoides percurrens*, *Apentalis* sp. (Braconidae), *Eupelmus* sp. (Eupelmidae), Unidentified (Ichneumonidae)*, Pupal: *Brachymeria* sp., *B. euploeae*, *B. obscurata* (Chalcididae), *Strumia* sp. (Tachinidae)* (2,5,6,7,9,11,19);c. Pathogen – *Bacillus thuringensis* (10); Nuclear Polyhedrosis Virus (1,12)	*P. deltoides* clones – [D-67 of USA/Alabama (33° N lat.); A37T100 of FGR/Alabama (USA)]; D92 of USA (Stoneville)] (3);[WSL-4,WSL-12,WSL-18,D-67,D-82,D-171] (13);[S7C4,D-171,82-42-5, WSL-64,3167,3324,S7C13,D-273] (14)
3. Poplar stem borer – *Apriona cinerea* Chevrolat (Coleoptera: Cerambycidae)	–	*P. deltoides* clone [G-48] (field observation)
B. Nursery pests		
4. Poplar Shoot Borer – *Eucosma glaciata* Meyrick (Lepidoptera: Tortricidae)	–	*P. deltoides* clones [G-48,G-43;C-3298,C-61 and L-75/84] (18)
5. Leopard Butterfly – *Phalantha phalantha (Lepidoptera: Nymphalidae)*	a. Pathogen: *Bacillus thuringensis* (10)	–
6. Poplar leaf Beetle – *Nodostoma waterhousie* Jac. (Coleoptera: Chrysomelidae)	–	*P. deltoides* clones [2504,3294,D-2354,3928,2054(1015),A-37(1001),3278,2652,G-48,2498 and D-2437(81)] (15)

References cited in this table: 1 – Ahmad and Sen-Sarma, 1983; 2 – Ahmad, 1992; 3 – Ahmad, 1993; 4 – Ahmad et al., 1996b; 5 – Ahmad et al., 1997; 6 – Ahmad et al., 1999;7 – Ahmad et al., 2001; 8 – Bhandari et al., 1988; 9 – Chatterjee and Mishra, 1974; 10 – Kalia and Joshi, 1996; 11 – Sen-Sarma and Gupta, 1981; 12 – Sen-Sarma and Ahmad, 1984; 13 – Singh, 2000; 14 – Singh, 2002;15 – Singh and Singh, 1995; 16 – Singh and Singh, 1986; 17 – Singh, 1998a; 18 – Singh, 1998b; 19 – Tyagi and Khan, 1993; *new records.

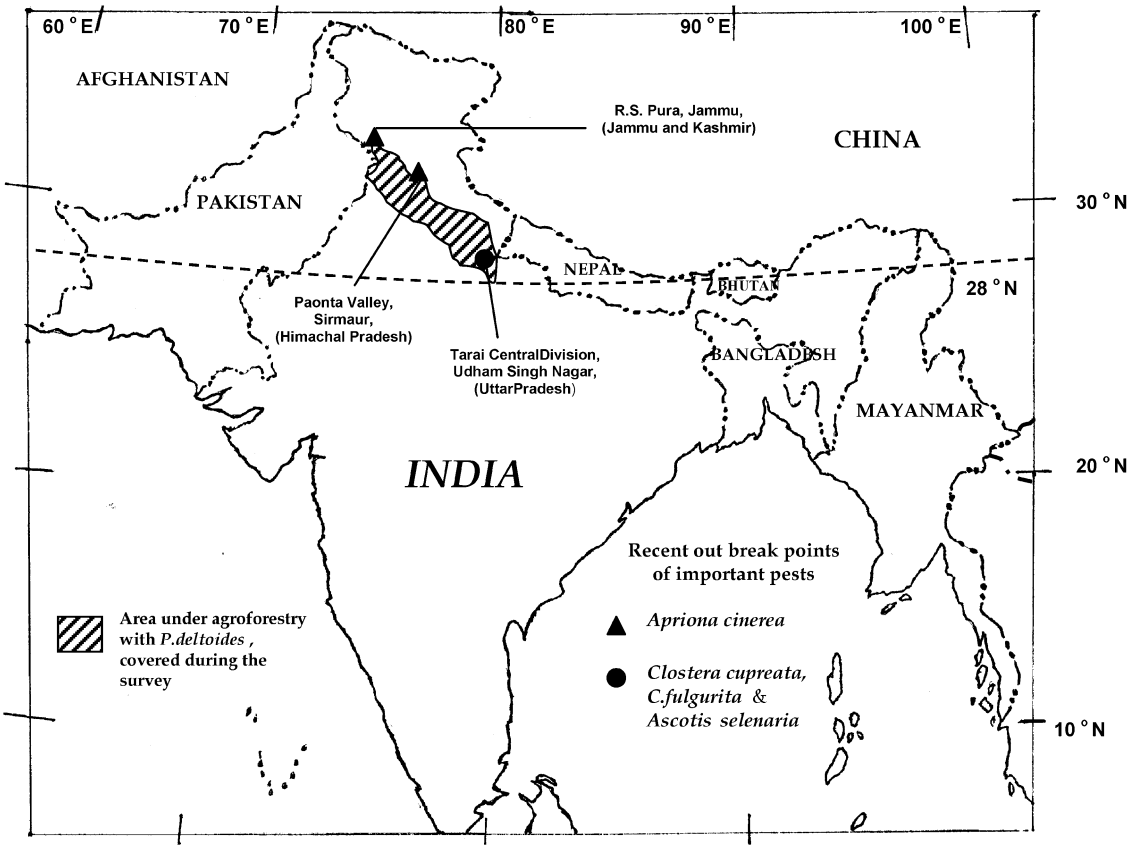

Figure 1. Map depicting the distributional range of *P. deltoides* plantations under agroforestry in northwestern India along with locations of recent (1984–2002) outbreaks of important insect pests.

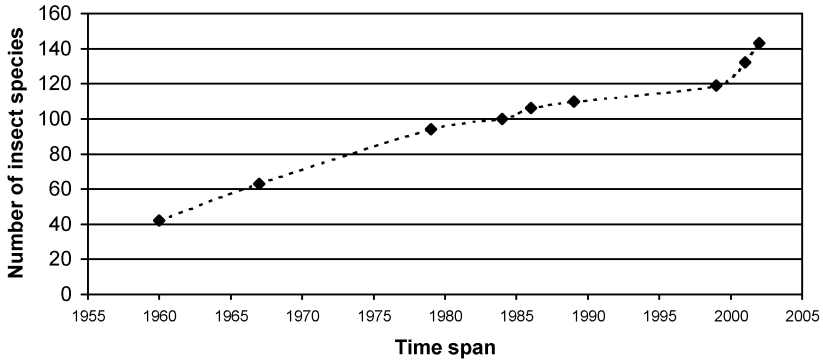

Figure 2. Cumulative growth of insect pest complex of poplars in northwestern India during the period 1960–2003 (June), as reported in literature.

tatomidae: Hemiptera) has been determined as a potential controlling agent for *Clostera* spp. [consumes from 86.5 to 159.9 larvae (of third to fifth instars) of *C. cupreata* during its entire predatory phase lasting 45 days, from second nymphal stage up to the death of the adult] and can be mass-reared easily in the laboratory (Ahmad et al. 1996b). Adults of an assassin bug, *Sycanus collaris* Fabr., (Reduviidae: Hemiptera) are also promising as they have been found to predate on one to three larvae (of third to fifth instars) of *C. fulgurita* per day in the laboratory (Singh 1998). Amongst the bio-pesticides, methanol extract of neem

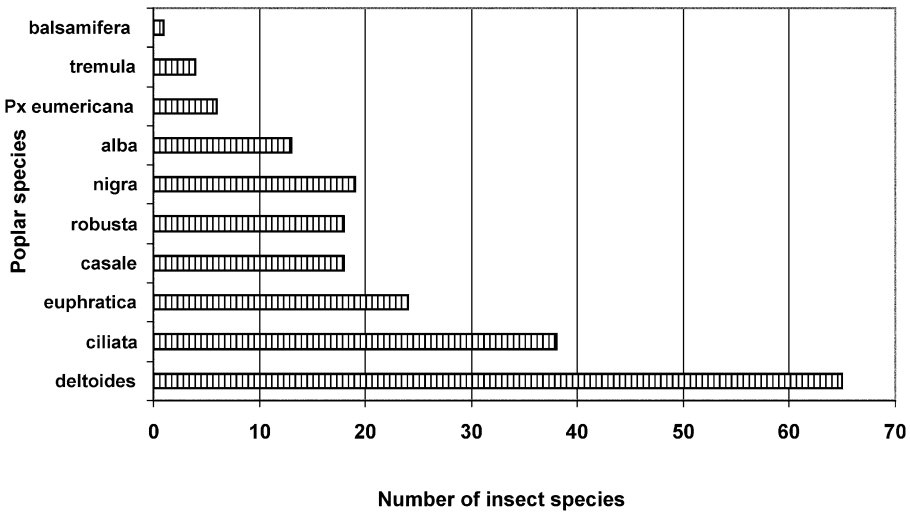

Figure 3. Relative susceptibility of *P. deltoides* to insects in relation to other poplar species growing in northwestern India (in terms of number of insect species infesting).

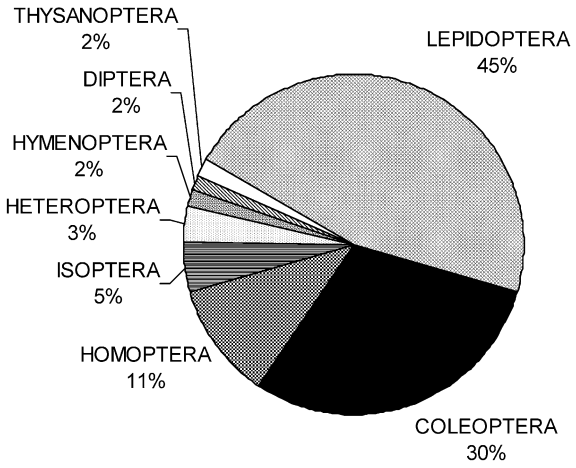

Figure 4. Relative representation of different insect orders (65 species) recorded feeding on *Populus deltoides* in northwestern India.

(*Azadirachta indica*) seed kernel, e.g., nemol or nemidine at 0.125% and 0.025% dilution, respectively, have very high degree of anti-feed ant property and can be sprayed after the rains (September) at the rate of 1000 ppm solution in water as a safe prophylatic alternative to control this pest and is recommended for field use (Bhandari 1988). In addition, N-butanol soluble fractions of leaves of *Adina cordifolia* were found to be effective against the *C. cupreata* larvae as it gave 19.99, 18.56 and 10.60 average mortality out of 20 larvae at 2.0, 1.0 and 5.0 per cent concentrations, respectively (Ahmad et al. 1996a). Spraying insecticides such as carbaryl (0.2%) or fenithrothion (0.1%) (Singh, 1988) or malathion (0.2%) (Verma et al. 1983) or cypermethrin (0.001%) in water also gives effective control of *Clostera* spp. and *P. phalantha*, during outbreaks. Collateral host plants (Table 2) of *Clostera* spp. and *P. phalantha* raised/growing nearby poplar plantations and nurseries, should also be surveyed regularly for keeping a check on pest population built up.

Leaf Beetle, Nodostoma waterhousie.
A considerable degree of natural control is brought about by parasitoids and extremely cold weather conditions are fatal for the adults of *N. waterhousie* (Singh 1986). Foliar spray of carbaryl (0.2%) or malathion (0.1-0.2%) (Singh 1986) during May–June is effective against the beetles in small heavily infested areas. Relatively tolerant *P. deltoides* clones (Table 3) against leaf beetles can also be planted in infestation prone areas (Singh and Singh 1995).

Sap suckers and gall formers

Aphids, Eriosoma sp.
Coccinellid predatory beetles (Table 3) that feed on the aphids are effective in suppressing their population. Galls made by the aphids can be removed and destroyed from time to time manually during winter. Planting of hybrid poplars also reduces gall infestations. Spray methyl-demeton (0.02%) or dimethoate (0.02%) or Monocrtophos (0.02%) when new flush of leaves come in spring (March) (FAO 1979; Verma et

al. 1983; Singh and Singh 1986) is also effective in checking this pest.

Root feeders

White Grubs (Holotrichia sp.*, Granida* spp.*, Brhamina* sp., etc.)
It is also not advisable to weed nursery beds during the fight period of the beetles (May–June) as the disturbance of the soil surface invites oviposition by beetles (Singh 1986). Clean cultivation and deep ploughing is recommended. Application of chlorpyriphos (0.2%) or phorate (10g) at the rate of 200 g/10 m^2 during May-June in nursery beds after soil working is advisable. Foliar spray with carbaryl (0.2%) twice at weekly intervals is effective against the defoliating beetles (Singh 1986).

Termites (Odontotermes spp. and *Copototermes* spp.)
Chlorpyriphos (0.2%) or endosulfan (0.2%) in water solution or their dust applied around the tree trunks during summer (June) is effective in preventing infestation.

Conclusion

The growth of insect pest complex of poplars in northern India (above 28° N) has shown a steady and phenomenal increase (Figure 2), with only 42 species reported on poplars until 1960, the comprehensive checklist now stands to ca. 143 species until June 2003. Today, *P. deltoides* has also been identified as the most susceptible species amongst the nine most widely planted poplar species in northwestern India (Figure 3). More than 65 insect species have been recorded infesting *P. deltoides* as compared to only 38 on *P. ciliata*, followed by *P. euphratica*; 24, and others, respectively, as per information gathered from previous studies. The reason for this may be extensive commercial planting of poplars mainly *P. deltoides* over large areas along side native vegetation complex in northwestern India (Chandra 2001). Insect species recorded feeding on *P. deltoides* are mostly indigenous to the Indian Sub-Continent, polyphagous and prefer to feed on exotic poplars over their native host plants. None of insect species has been imported or introduced into India along with the poplar germplasm from native countries. Poplars cultivated in monoculture provide ready food for these local pests and loci for outbreaks. The 64 species recorded on *P. deltoides* belong to 31 families from eight different insect orders (Figure 4). Members of the family Lepidoptera dominate the complex followed by Coleoptera and Homoptera, respectively. While, rest of the other families (Isoptera, Hemiptera, Hymenoptera, Diptera and Thysanoptera) represent only 14% of the spectrum.

Recent (2002) insurgence, by a minor pest, known until now in the region, has surfaced in *P. deltoides* plantations, which is a cause of worry. A polyphagus defoliator, *A selenaria*, has now been observed establishing in plantations (central Tarai region of Uttaranchal state), where *C. fulgurita* population gets been wiped out NPV, which results in heavy defoliation although on a localized scale.

Although control of majority of the pests is brought about in the field by natural enemies already present there, however some species are capable of multiplying in great numbers and cross the economic injury levels especially the absence natural enemies and favorable climatic conditions. As a part of integrated pest management, which uses natural mortality factors to the maximum extent, proper cultural methods must be applied and practiced timely for keeping at check on pest populations at levels where they are unable to cause economic losses to growers. More importantly non-chemical methods are relatively economically cheaper and safer to use as compared to other control options available. Avoiding pests by planting tolerant poplar hybrids/clones, removing native or avoiding alternate host plants of the pest, in infestation-prone areas is advisable. Besides, sequential release, augmentation and establishment of natural enemies in outbreak areas supplemented with the use of bio-pesticides, as potential biological weapons against these pests, are much safer to use for the environment and need of the hour. The use of insecticides should be minimal and applied cautiously, as their indiscriminate use will not only lead to imbalances in the component species of poplar ecosystems but also pose operational difficulties particularly when poplar are raised in the mountainous areas of the country. The use of chemicals should thus be restricted to nurseries and young plantations and applied as the last option. It is hoped that this updated information will serve as a ready guide for tree breeders, entomologists, farmers and plantation companies, involved with the growing of poplars.

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