Introduction

Trees are increasingly grown on farmland to supply wood and biomass in both temperate and tropical climates, both as in developed and developing countries (Zomer, et al., 2007). In developing countries, forests are the main source of timber, fuel wood, pulp and paper and livelihood for a large number of villagers and forest dwellers. Notably, forests are second only to oceans in the biological sequestration of carbon, and they are recognized for their vital role in regulating the concentration of the greenhouse gas, CO₂. At the same time, forests are threatened by land clearing for development and agriculture, introduced pathogens and insects and by climate change. With the growing concern for the rapid depletion of forests, several countries have encouraged wood-based industries to develop tree plantations for meeting the needs of the local people and conserving the forest wealth and environment (Jain and Singh, 2000; Jansson et al., 2010). Increasing demands for wood based structural materials with decreasing quality and quantity of raw materials are forcing the industry to utilize fast growing trees that have unfavorable properties (Bejo and Lang, 2004).

Grows fast! Grows anywhere! Super tree!- these are just a few of the claims that have been made for hybrid poplars in recent years (Ostry and McNabb 1990). Poplar is an environment friendly plant species, having alternative source of raw material for pulp production due to their potential fast growth (Kirci and Akgul, 2002). Poplar (Populus deltoides), a fast growing and short duration forest crop, is grown on irrigated and fertile lands. As a result, large chunks of irrigated and fertile lands are being brought under poplar-based agroforestry. Over the last several decades, within the irrigated rice-wheat growing lands of northern India, a considerable number of fast-growing poplar trees have been planted on tens of thousands of small farms.

Species of genus Populus (commonly known as aspens, cottonwood and poplars) are deciduous, or rarely, semi evergreen trees that occur primarily in the boreal, temperate and subtropical zones of the northern hemisphere (Eckenwalder, 1996; Dickmann, 2001; Cronk, 2005). Poplar belongs to the family Salicaeceae, order Salicales and group Amentiflorae (Dickman and Stuart, 1983; Eckenwalder, 1996). Poplar in the natural range occurs interspersed through the forest of temperate region of northern hemisphere between the southern limit of around latitude 30° north and northern limit
latitude 45°N. Exotic poplars were initially introduced in India in area between 28° to 31°N. That is how, poplar have very specialized climatic and edaphic requirements which restrict their cultivation in India (Tewari, 1993).

Poplar is a large tree reaching well over 25 meter in height and 100-130 cm in girth (Tewari, 1993); in a period of 10 – 12 years, and it develops a tall, straight bole. Poplar are light demanding plants and susceptible to drought. Though they grow well on sites with high water table, but cannot withstand water logging. The growth is optimal under irrigated conditions. Poplar mostly occurs in low-lying, moist alluvial ground, tolerates flooding for a short time during the rainy season, and are routinely be propagated vegetatively (Lodhiyal et al., 1994). *P. deltoides* enters in dormancy during winter, therefore, suited well to companion crops for ensuring food production and also enhances economic returns to the growers (Chauhan et al., 2012).

Important countries where poplar planting was initiated to meet the challenge of increasing demand and shortage of wood supply are France, Germany, Hungary, Korea and Spain. In India, poplars (*P. deltoides*) are eminently suited for agroforestry and are being in Uttar Pradesh, Uttaranchal (now Uttarakhand), Punjab, Haryana and Jammu & Kashmir (Singh et al., 1999; Rizvi et al., 2008). In northern India, it is an agro-forestry tree because of its fast growth, straight- growing stem, short rotation, quality wood production and less adverse affect on agriculture crops (Bangarwa, 2008). In the interspace of poplar plantations, several seasonal crops are cultivated for enhancement of overall productivity of the land and generation of supplementary income (Jaiswal et al., 1993; Singh et al., 1993; Jain and Singh, 1999).

There are 35 species of poplar currently recognized in the world; out of those 6 *Populus* species are indigenous to India, namely, *P. alba, P. ciliata, P. euphratica, P gamblei, P glauca* and *P suaveolens*, representing five sections of *Populus* (Mathur and Sharma, 1983). Some experts consider *P. alba* and *P. euphratica* as exotics (Naithani et al., 2001). In addition, *P. nigra* has naturalised itself in Kashmir valley (Kumar et al., 2005). Indian forests, of about 21 M ha, are now insufficient to support the fiber industries and, therefore, many fast growing exotics have been introduced in the country to fulfill the pulpwood demand quickly (Singh, 1998). *P. deltoides*, a native tree of the USA, was introduced in India in 1950s (Balatinecz & Kretschmann, 2009).
Poplars are among the world’s fastest growing industrial softwood which can be used as pure or mixed plantation as well as in association with agriculture crops (Jha, 1999). They are mostly multipurpose tree species (Anonymous, 1979; Dickmann and Stuart, 1983). The wood of *P. deltoides* is used for large spectrum of products (around three dozen products; Dhiman, 2004), such as plywood, pulp, paper, fiber, fuel, structural timber, wood for poles, packages, matches, chopsticks, tannin/dyestuff and biomass production. It offers a great potential for meeting the requirements of the farmers and wood-based industry in the country. It is planted world-wide for wind shelters, soil erosion control, water/soil conservation, phytoremediation, etc. (Singh and Singh, 1986; Stettler *et al*., 1988; Ziabari, 1993; Ceulemans & Deraedt, 1999, Ghasemi, 2000; Kiadaliri, 2003; Ball *et al*., 2005; Sharma & Sharma 2005; Bradshaw *et al*., 2007; Zalesny & Bauer, 2007; Acker *et al*., 2011; Marmiroli *et al*., 2011). Due to its fast growth and wider adoptability, the tree has also huge potential to sequester carbon and mitigate CO₂ from the atmosphere (Chauhan *et al*., 2009; Dhiman, 2009; Singh and Lodhiyal, 2009; Chauhan *et al*., 2010; Gera, 2012).

In India, poplar is grown under forestry programmes as clonal plantations to ensure the genetic superiority for better growth and superior wood quality (Pande & Dhiman, 2010). Meanwhile, favoured by their simple clonal propagation, relatively rapid growth rate and considerably small genome size among woody species, they are one of the major model plants used in both scientific and industrial research (Bradshaw *et al*., 2000; Polle and Douglas, 2010). Poplar trees belonging to different species can frequently cross each other, creating valuable hybrid types and most are easily propagated by vegetative means. By taking cuttings from a single tree, infinite number of genetically identical trees can be produced - better known as clones (Charlton *et al*., 2007). Several promising clones of *P. deltoides* namely; G, D, Sc, I, IC, PL, St, L, WSL, Wimco series, etc., have been identified and, subsequently, planted in farm/agro forestry systems throughout Punjab, Haryana, Tarai region of Uttarakhand, western part of Uttar Pradesh, some parts of Bihar, West Bengal and Assam (Mishra *et al*., 2010; Dhiman & Gandhi, 2012).

The clonal forestry in India represents a very narrow genetic base of the planting material. Clones, being raised as monocultures, are thus prone to a large number of
fungal pathogens and disease outbreaks (Singh et al., 2012). While, the potential for rapid growth exists; poplar productivity is frequently reduced by diseases (Widin & Schipper, 1981; Broderick et al., 2010). The negative effects of pathogens on poplar growth have inspired breeders to make disease resistance as the major selection criterion in poplar tree improvement for last 50 years. In spite of these efforts, in most poplar-growing areas, few clones combine necessary disease resistance with desirable form and growth characteristics (Newcombe, 1996). In nineties, it was emphasized to start a coordinated performance trial so as to evolve local sustained clones from the exotic poplars. By the use of limited number of clones, there always remained a risk of disease/pest outbreak; moreover, continuous vegetative propagation also deteriorated the quality of clones. Because of which, the new clones were continuously been introduced and old replaced by the new ones to broaden the genetic base (Dhiman, 1967; Lohani, 1967; Qureshi, 1967; Pande, 1973; Khurana and Khosla, 1978; Sidhu, 1994, 1996; Burfal et al., 2001).

Trees in the genus *Populus* can provide substantial commercial and ecological benefits including sustainable alternatives to traditional forestry. Realization of their potential requires intensive management; but damage by pests can severely limit productivity in such systems (Widin & Schipper, 1981; Broderick et al., 2010). Poplars are host to numerous pathogens (primarily fungi) that can lead to diseases of all parts of the tree. In addition, they are subject to insect pests and environmental stresses that can predispose them to other fungi that are not normally harmful to healthy trees (Ostry et al., 1989). Monoculture (single species) tree plantations are considered to be at greater risk from attack by pests and diseases than forests of mixed species, partly because they are an easy target for insects to find in the landscape. Many monoculture plantations around the world are of non-native species, chosen for their fast growing rate. However, introduced trees may respond differently to native tree species when attacked by local insects and diseases (http://ec.europa.eu/environment/integration/research/newsalert/pdf/306na5.pdf, 2014). In agro-forestry, the situation may further aggravates, where pathogens often diverse their activity from the common host range and cause extensive damage to either of the inter-crop species.

Large numbers of foliage diseases were recorded in poplar nurseries. Fungi causing leaf spots and blights are *Alternaria alternata*, *Bipolaris* spp., *Cercospora*
populina, Cladosporium humile, Corticium salmonicolor, Curvularia sp., Drechslera maydis, Fusarium solani, Pollaccia sp., Phoma, Phyllosticta adjuncta, Rhizoctonia microsclerotia, Sclerotium rolfsii and Septoria (Pandey and Khan, 1992; Singh et al., 2012). Curvularia leaf spot caused by *C. lunata* on *P. deltoides* is reported from Punjab (Gupta et al., 2001). However, it is also reported on *P. nigra* from Morocco by Drider et al. (2012). During the field surveys between 2008-12, Curvularia leaf spot was observed on several commercial clones of *P. deltoides* (G-48, Uda1, WSL-22 & WSL-39), underlying their wide presence. The fungus is, otherwise, known to be a weak pathogen (Butler, 1953; Hodges and Campbell, 1995; Kilambi, 2005; Smiley et al., 2005). Its presence on many commercial poplar clones may add to the widely believed fact that the climate change may affect the population composition and structure of the pathogens under field conditions. Fungal pathogens are often strongly dependent on humidity or dew for plant infection (Huber & Gillespie 1992), so changes in these environmental factors are likely to shift disease risk. The changes in temperature and other climatic factors may activate some sleeper pathogen species while; others may cease to be economically important. This may apply equally to endemic and exotic pathogens (Chakraborty et al., 2008).

Species of *Curvularia* occur mostly as tropical and subtropical facultative plant pathogens with teleomorphic states in *Cochliobolus* and *Pseudocochliobolus* (Rossman et al., 1987). A number of *Curvularia* spp. have been reported as casual agents of seedling blights, grain discoloration and lesions, rice grain deformation, kernel rot, leaf spots and blight and root rot (Ellis, 1971; Kim- Jisoo & Lee-Du Hyung, 1998; Sisterna & Bello, 1998; Parimelazhagan & Francis, 1999; Rashid, 2001; Singh et al., 2001). The genus *Curvularia* is known to be pathogenic on a number of monocotyledon host (Barron, 1968). Curvularia leaf spot also affects many species of grasses worldwide and commonly caused by *C. eragrostidis, C. geniculata, C. intermedia, C. inequalis, C. lunata, C. pallescences, C. protuberate* and *C. trifolii* (Agarwal and Sahani 1963; Noble & Richardson, 1968; Benoit & Mathur 1970; Barua & Bordoloi, 1983; Smith et al., 1989). *Curvularia* spp. were also recorded as important pathogen of various agriculture crops (Mitra, 1921; Kulkarni, 1921; Patil et al., 1965; Jain, 1962; Mandokhot & Chaudhary, 1972; Cook, 1981).
Many species of *Curvularia*, were also recorded on several forestry trees species. For example, *C. eragrostidis*, *C. geniculata*, *C. lunata* and *C. pallescens* have been reported to causes diseases in seedlings of eucalypt (Gibson, 1975; Sharma, 1986; Jamauluddin et al., 1987). *Curvularia* sp. also affects teak (*Tectona grandis*) in India (Balasundaran et al., 1995). *C. lunata* causes dieback on *Acacia nilotica* (Singh and Jamaluddin, 1995). Curvularia leaf spot by *C. lunata on P. deltoides* is reported from Punjab state of India (Gupta *et al.*, 2001). *C. affinis* causes black leaf spot of mulberry and leaf spot of *Dalbergia sissoo* in India (Rao *et al.* 1992; Sharma *et al.*, 2012).

The recent changes in climate are altering the pathogenic succession and pathogens like *Curvularia, Alternaria*, etc. are appearing in epidemic proportions on several clones of poplars (G-48, Udai, WSL-22, WSL-39 etc.). Poplar is an important species for ecology and economy of temperate and tropical country of the world. So, any losses in terms of its diseases may also affect its economy. Such pathogens, in future, may cause large scale damage to the tree crop leading to substantial economic losses to the growers. Only resistant clones are answer to such problems as chemical management may not be eco-friendly and practical. For development of an effective programme of breeding for disease resistance, a comprehensive understanding of casual organism with reference to morphological, cultural, physiological and pathogenic variations are essential. Such studies are very much lacking in case of Curvularia leaf spot on *P. deltoides* due to limited information about the disease (Gupta *et al.*, 2001). There is no record of Curvularia leaf spot symptoms on *P. deltoides*, its pathogenicity, morphological and physiological variation and management of the pathogen, and role of toxin in pathogenesis. Keeping this in view, the following objectives were set for investigation:

   a) Survey of nurseries for collection of *Curvularia* sp. isolates from different commercial clones of *P. deltoides*.

   b) Defining the Curvularia leaf spot symptoms.

   c) Study of morphological (colony characterization) and physiological (growth and nutritional requirements) diversity of the pathogenic isolates.

   d) Study of abiotic (fungicide sensitivity) and biotic interactions (with antagonist, co- habitant & among isolates ) of the *Curvularia* sp. isolates.

   e) Screening for resistance of poplar genotypes against *Curvularia* sp. toxin (s).