Environment is the sum of substances, forces and conditions external to an organism that influence its various components and constitutes a multidimensional system of complex relationships in a continuing state of change. Land, air and water, with their flora and fauna, constitute environment for man who depends on environment and simultaneously becomes an environmental factor for other members in the ecosystem. Man has been facing problems in maintaining himself and his descendents on earth since his existence. Light, temperature, atmospheric humidity, air quality, soil features, wind and altitude are the various environmental factors which work in conjunction but not in isolation, thus, results the organisms in a holistic manner. It alters the natural balance in the environment when quality or magnitude of any one factor changes and may cause a variety of stresses on the organisms or objects of a given ecosystem.

Air, water, food, heat and light are essential for human existence. Plants are more dependent of the environment as they are permanently attached to soil to absorb water and nutrients and exposed to air for gaseous exchange and light absorbance. Pure air consisting of a gaseous mixture of nearly 78% of nitrogen, 21% of oxygen and one percent of carbon dioxide, nitrogen dioxide, ozone, sulphur dioxide etc. is necessity of animal and plants. A change in the relative proportion of the gases beyond the self regulating capacity of the environment is commonly known as air pollution and is injurious for plants and other organisms.

The air pollutants originating from natural or anthropogenic sources may be organic (hydrocarbons) or inorganic (CO, SO₂, NOₓ, O₃, PAN, acid rain, etc.) based on chemical composition. Air pollutants are of two kinds, primary pollutants and secondary pollutants depending on their formation. Primary pollutants are those which are toxic to plants in the form generated from the source eg. SO₂, NOₓ, H₂S, NH₃ etc. Secondary air pollutants are formed due to reaction between primary pollutants in the presence of sun light.
(UV) eg. \( \text{O}_3 \), PAN etc. The pollutants may be produced by natural events (dust storm, volcanic eruptions, forest fire, sea spray or plant pollen etc.) or human activities (industrial emission, vehicular discharge, nuclear explosion, solid waste disposal and some domestic activities).

Sulphur dioxide is an important phytotoxic air pollutant especially in the countries where fossil fuels are excessively used. In India and other developing countries coal is a major source of energy to run industries, hence, \( \text{SO}_2 \) has become a major and prevalent air pollutant. In addition to coal burning, other sources of \( \text{SO}_2 \) pollution are volcanic eruptions, fossil fuel combustion, metal smelting and oil and natural gas processing.

In addition to gaseous form, \( \text{SO}_2 \) also contributes in the formation of acidic precipitations. The gas combines with moisture in the atmosphere, giving rise to acid rain, a rainfall which is acidic or more acidic than the normal natural water. Normally, pH of water ranges between 6.5 and 8.5 if the water pH goes below 6, the water is considered to be acidic. In India, some cities like Kolkata, Mumbai and Pune are reported to receive acidic rains which largely occur in the developed/industrialized country.

Sulphur dioxide enters into plants through open stomata of leaves. The absorbed \( \text{SO}_2 \) is converted into sulphite and sulphate ions which are known to inhibit irreversibly both cyclic and non-cyclic photophosphorylations by affecting the coupling factor of chloroplast thylakoids (Ryrie and Jagendrof, 1971) and Calvin cycle enzymes in leaves (Ziegler, 1972; Libera, 1975; Tanaka et al., 1984). At high concentrations such as 1 or 2 ppm \( \text{SO}_2 \), photosystem II is inhibited irreversibly and the possible site of inhibition is close to the reaction centre (Shimazaki and Sugahara, 1980). Appreciable acidification of stroma and accumulation of \( \text{H}_2\text{O}_2 \) could lead to the inactivation of several key enzymes necessary for \( \text{CO}_2 \) fixation.

Exposure of plants to \( \text{SO}_2 \) leads to development of visible foliar injury and symptoms. The injury may be of two types, chronic and acute. The chronic injury is characterized by prolonged exposure to low concentrations of \( \text{SO}_2 \) (eg. 0.02 ppm for months) and accumulation of sulphate ions. The acute injury
results from short term exposure to high concentrations and accumulation of sulphite ions. Sulphur dioxide at 0.25 ppm for 8 h or 0.95 ppm for 1 causes acute injury in the form of tissue discolouration, necrosis etc. and significant reduction in plant growth and yield.

Sulphur dioxide has been recognized as inanimate or abiotic pathogen and harms plants by suppressing their growth and dry matter production. These adverse effects occur through inhibition in the photosynthesis rate and reduction in chlorophyll pigments (Ali, 1998; Iqbal et al., 2000a). Sulphur dioxide has been reported to cause significant suppression in the plant growth and/or yield of a number of crop plants such as tomato (Khan and Khan, 1991; Khan and Khan, 1994b; Khan and Khan, 1998), egg plant (Khan and Khan, 1997), cowpea (Khan and Khan, 1996a), okra (Khan and Khan, 1994a), soybean (Singh et al., 1996; Singh et al., 1997), bottle gourd (Khan et al., 1991b; Khan and Khan, 1998) and pea (Kumar and Prakash, 1990; Singh et al., 1995; Singh et al., 1996, Prakash et al., 1997). There are limited information on effect of SO$_2$ exposures on plant growth and yield of mustard (Khan et al., 2007). But in view of large foliage and expanded leaves, the crop is likely to be affected by SO$_2$.

Plants in nature may be attacked simultaneously by abiotic and biotic pathogens. When these two kinds of pathogens co exist in a common environment may interact and develop some relationship, which may be as follows.

(a) If air pollutants, directly or indirectly through the host plant are toxic to biotic pathogens, they may suppress the disease and subsequently an antagonistic interaction would occur.

(b) The pollutants may predispose the host plant for greater invasion and damage by the pathogen(s) by modifying host physiology and/or injuring the host tissue so as to make the plant much susceptible or easily invadable by the pathogen. This may lead to a synergistic relationship between pollutant and pathogen or vice versa, thus causing greater damage to the host plant.
(c) Both pollutant and pathogen may act independently without influencing the activity of each others.

Exposures to SO$_2$ may eventually lead to the accumulation of sulphur, increased acidity and other changes in plant physiology and biochemistry that may affect pathogenesis of microbes and subsequently the disease development. The environmental pollution may have a direct effect on plants and pathogens and it may alter the host parasite relationship influencing virulence of the pathogen and/or susceptibility of the host. Direct effect of SO$_2$ on fungal spores has been investigated in ambient and simulated conditions as well as \textit{in vitro}. Since long germicidal nature of SO$_2$ has been known to man but probably such observation in ambient condition was first made by Kock (1935) when he noticed absence of powdery mildew fungus, \textit{Microsphaera alni} on oak trees in the vicinity of a paper mill in Australia.

Industrial emissions containing SO$_2$ may decrease incidence of the disease caused by various fungi viz. \textit{Alternaria solani}, \textit{Hypodermella juniper}, \textit{Hysterium pulicara}, \textit{Rhystisma acerinum}, \textit{Sphaerotheca fulginea} and \textit{Venturia inaequalis} etc. (Scheffer and Hedgcock, 1955; Przybyski, 1967; Rai, 1987; Khan \textit{et al.}, 1991b). With a gradual increase in distance from the smelter, there was a corresponding decrease in plant injury and increase in the incidence of fungal diseases (Rai, 1987; Khan \textit{et al.}, 1991b). Quite contrary to the above findings, a few reports show stimulatory effect of SO$_2$ on the fungal pathogenesis. Conidial germination of powdery mildew viz. \textit{Erysiphe trifolii}, \textit{E. pisi}, \textit{E. polygoni}, \textit{Microsphaera alphitoides}, \textit{Phyllactinia dalbergiae}, \textit{Sphaerotheca fulginea} and \textit{S. cassia} were suppressed on exposure to 0.1 and 0.2 ppm SO$_2$ (Khan and Kulshreshtha, 1991). The 50 ppb SO$_2$ increased the severity of powdery mildew on cucumber caused by \textit{Sphaerotheca fulginea} (Khan \textit{et al.}, 1998). Higher concentration (200 ppb), however, suppressed the disease, and the fungus colonization partially protected the plants from SO$_2$ injury. Fungal spores are quite resistant to SO$_2$ but they may become sensitive under moist and humid condition. Germination of wet conidia of \textit{Alternaria} sp. decreased by 60\% from exposure to 50 ppm SO$_2$ for 24 minutes, however, 110
ppm produced similar effects on dry spores (Couey, 1965). Exposure at 100 and 200 ppb SO$_2$ caused inhibitory effect on the colonization of *Alternaria alternata* and *A. brassicicola*, but sporulation and spore germination were stimulated at 100 ppb SO$_2$ for 3-9 h (Couey and Uota, 1961; Wani et al., 1997).

The demand of vegetable oil for human consumption in the world is principally derived from oilseeds. In the agricultural economy of India, oilseeds constitute the second major agricultural commodity next to food grains in terms of area, production and value. Currently, India accounts for about 13% of world’s oilseeds area with 7% of the output, and 10% of world’s edible oils consumption. The diverse agro-ecological conditions in the country are favourable for cultivation of all the nine annual oilseeds, including seven edible oilseeds, viz. groundnut, rapeseed-mustard, soybean, sunflower, sesame, safflower and niger and two non-edible sources, viz. castor and linseed.

Rapeseed-mustard group of crops is among the oldest cultivated plants in human civilization. Biologically, the rapeseed and mustard plants belongs to the family Brassicaceae under the genus *Brassica*. The different types of oil yielding *Brassica* crops are commonly referred as rapeseed-mustard, and comprising of four species viz., *B. juncea* L. Czern and Coss (India mustard), *B. campestris* L. (Turnip rape), *B. napus* L. (Winter rape) and *B. carinata* Braun (Ethiopian mustard). These oilseeds Brassicas are best adapted to areas having a relativity cool moist climate during the growing season and dry harvest periods, hence grown in tropical, sub-tropical and temperate zones of the world viz., India, China, Pakistan, Bangladesh, Poland, Canada, France, Sweden, Germany, England, Australia and Russian states (Kolte, 1985; Mukerji et al., 1999). On the Indian subcontinent, *B. juncea* is the dominant species grown in India. These species are regarded as of Asiatic origin. It is largely grown under the hardy conditions of rainfed agriculture with low input management during *rabi* season, but have a good inherent potential to convert natural resources into usable biological energy.

Rapeseed-mustard is cultivated in 53 countries spreading over six continents across the globe covering an area of 24.2 million hectares with an
average yield of 1451 kg/ha ranging from 411 (Russian federation) to 6250 kg/ha. (Algeria) and netted the total production of 35.1 million tonnes. Asian continent alone contributes 59.1% of the hectarage and 48.6 % of the world’s production. In Asia, it is chiefly grown in China, India and Pakistan. Among the 7 Asian countries, China and India together contributes 95.4% of total hectarage and 96.7% of production of rapeseed and mustard. India alone contributes 28.3% hectarage and 19.8% production of the Asian countries. The projected demand of oilseeds in India is around 34 million tonnes by 2020, of which about 14 million tonnes is to be met by rapeseed-mustard (Yadava and Singh, 1999).

In India, the rapeseed-mustard is the most important oilseed crop accounting around 25% of total oilseed production and the oil obtained accounts for two third edible oil consumption in the country. It is estimated that about 90% of domestic production of rapeseed-mustard is crushed for extracting edible oil, which is mostly traded and consumed in northern, eastern, north eastern and central India. The recently promoted ‘canola’ quality hybrid rapeseed namely ‘Hyola’ has a good potentiality as a profitable enterprise for farmers as it gives a higher yield, more oil content, good export quality and an assured market. Besides, the utilities of oil obtained from rapeseed-mustard, the seeds, sprouts, leaves, tender plants are also useful to human health when they are consumed as spices and vegetables. They contain selenium, calcium, magnesium, iron, phosphorus, zinc, magnesium, manganese, etc.

The productivity rate of rapeseed-mustard is considerably low in comparison to other countries such as Algeria, France and Canada. There are indeed, multitudes of factors which are responsible for a lower productivity and yield declines. Among major constraints, the occurrence of diseases and insect pests appears to be an important factor which have restricted fast expansion of its cultivation and abate productivity of these crops. There are about thirty diseases, which are reported to occur on this crop and of these very few are of economic importance (Kolte, 1985; Rajak, 1999; Mukerji et al., 1999; Hegde, 2002). Among these, Alternaria blight is considered as of major consequences
on the basis of their wide distribution and yield losses caused to Brassica spp. world over including India (Kolte, 1987; Khan et al., 2010). This disease is caused by three species of Alternaria viz., A. brassicae (Berk.) Sacc, A. brassicicola (Schw.) Wilts. and A. raphani Groves and Skolko, however, former two species are principal causal pathogens of the disease. They are widespread in occurrence and destructive in nature causing significant damage to rapeseed-mustard production throughout the country.

The disease is characterized by formation of lesion on leaves, stem and siliquae. Nevertheless, lesions produced by A. brassicae appear usually as gray compared to the black sooty velvety spots produced by A. brassicicola. Spots of A. raphani show distinct yellow halos around them (Kolte, 1985; Mukerji et al., 1999). Besides leaf infection reducing the photosynthetic area, the infection also leads to deteriorate the quality of the seeds i.e., seed size, seed colour, oil contents and germination capability (Randhawa and Aulakh, 1981; Khan et al., 2010). The disease may cause yield loss of upto 46-47% in yellow sarson and 35-38% in mustard but in susceptible cultivars the losses may be as high as upto 70% (Kolte, 1985; Saharan, 1991; Vishwanath and Kolte, 1997, Prasada et al., 2003).

The pollutants may (a) prove toxic to pathogen and suppress its pathogenicity, thus protecting the plant against the plant pathogens, (b) predispose the host plant to greater invasion and damage by the pathogens, or (c) may act on plant independently without affecting the efficiency of the pathogens (Khan and Khan, 1993b).

Critical analysis of the information available on pollutant-pathogen interaction has revealed that the investigations carried out on the aspect are inadequate to ascertain the effect of air pollutants on plant diseases. In India, a similar situation of coexistence of SO₂ and plant pathogenic fungi exists in fields around coal fired industries and other SO₂ sources. Some studies have revealed both inhibitory and stimulatory effects of air pollutants on plant pathogens. Hence, this aspect of research was taken under the Ph. D. programme to examine and ascertain the effect of SO₂ on the leaf blight of
mustard caused by *A. brassicae* or *A. brassicicola* and vice versa. It was intended to know whether the Alternaria blight becomes suppressed or intensified in SO$_2$ polluted environment, and is there any effect of fungal infection on sensitivity of plants to SO$_2$? Following experiments were conducted to achieve the above objectives.

i. Evaluation of performance of different methods of inoculations with *Alternaria brassicae* and *A. brassicicola* on Indian mustard.

ii. Evaluation for resistance/tolerance of indigenous germplasm of Indian mustard against *Alternaria brassicae*.

iii. Evaluation for resistance/tolerance of indigenous germplasm of Indian mustard against *Alternaria brassicicola*.

iv. Evaluation for resistance/tolerance of indigenous germplasm of Indian mustard against intermittent exposures of sulphur dioxide at 25, 50 and 75 ppb.

v. Effect of intermittent exposures of 25, 50 and 75 ppb SO$_2$ on the development of Alternaria blight caused by *Alternaria brassicae* on germplasm of Indian mustard.

vi. Effect of intermittent exposures of 25, 50 and 75 ppb SO$_2$ on the development of Alternaria blight caused by *Alternaria brassicicola* on germplasm of Indian mustard.