Chapter-5

Discussion
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DISCUSSION

The atmosphere is being loaded with undesirable amount of harmful gases and the particulate suspended matter, released mainly from the exhaust of the ever increasing number of industries, using coal as a cheap source of energy. The condition seems to be more alarming in developing countries, adopting rapid technological and industrial advancements without following appropriate emission control measures.

These pollutants have significant impact on all the organisms, including plants. However, I am here mainly concerned with two important atmospheric pollutants (sulphur dioxide and fly ash) whose interaction with the physiomorphological and yield characteristics, of two locally cultivated oil yielding crops (rapeseed and sunflower) has been studied. Moreover, these pollutants are also known to interact variedly with the fungal plant pathogen and the host. The rapeseed pathogen, *Alternaria brassicicola* was, therefore, also included in this study. The experiments were planned in a way so that SO₂ level in the atmosphere and the contents of fly ash in the soil and at the level of the plants could be maintained approximately parallel with that of the agricultural fields around the Kasimpur Thermal Power Plant, located 15 Km away from the campus of the Aligarh Muslim University, Aligarh.
5.1 Impact of $\text{SO}_2$

The simple physiological phenomenon of diffusion allows the entry of $\text{SO}_2$ into the foliage tissues of the plants, largely through the stomata (Barret and Benedict, 1970). It reacts with the water molecules to produce sulphite ions (Thomas et al., 1944) which are slowly oxidized to sulphate ions (Pell, 1979). Their presence, in larger quantities, is toxic to plants as these ions are responsible for photodestruction (Nieboer et al., 1976; Malhotra, 1977), destruction and/or phaeophytinization of the chlorophyll molecules (Rao and Le Blanc, 1966). Moreover, disruption in the synthesis of the pigments is probably due to the interference of $\text{SO}_2$ in various metabolic processes (Varshney and Garg, 1979; Pierre and Quieron, 1982; Tanaka et al., 1982; Khan and Khan, 1993) resulting in the decrease of the photosynthetic efficiency of the plants (Thomas, 1951; Weinstein and McCune, 1970; Sharma and Prakash, 1991; Singh et al., 1994). The sulphite ions also compete for the binding sites at the thylakoid membrane in the chloroplasts (Wellburn, 1988). This impact of $\text{SO}_2$ on the structural units of the chloroplasts and/or the chlorophyll molecules may be assigned as the primary reasons for the observed decrease in the level of the chlorophylls and carotenoid whose concentrations decreased linearly with an increase in the atmospheric $\text{SO}_2$ (142.85 to 571.43 $\mu\text{g m}^{-3}$) both in the rapeseed (Tables 5, 6) and the sunflower (Tables 34, 35). It finally ends in the observed necrotic lesions at the foliage and a decrease in the availability of photosynthates at the source (leaves), thus hampering over all growth of the plants (Thomas, 1951;
Weinstein and Mc.Cune, 1970; Tables 2-4 and 31-33). Such a lean state of metabolism, at the level of the foliage, will not possibly be in a position to generate a proper sink for mobilizing the elements, absorbed by the roots, to the shoot. Moreover, a supply of insufficient quantity of the photosynthates to the roots, from the stressed leaves, should have restricted the growth (Tables 2-4 and 31-33) and the nutrient absorption capacity of the roots. Therefore, the level of all the nutrients, except sulphur, declined in the leaves of both the crops with the successive increase in the level of SO$_2$ (Tables 7-8 and 36-37). Similarly, a decrease in the level of nitrogen, in other cultivars, exposed to SO$_2$ has been reported by others (Mishra, 1980; Sardi, 1981; Kumar and Prakash, 1990).

The plants, therefore, have a limited amount of nutrients and photosynthates (Whitemore and Mansfield, 1983) on their disposal which will obviously restrict their overall growth. It is quite prominent both in the rapeseed and sunflower where the values for all the parameters of the shoot and the root (Tables 2-4 and 31-35) decreased significantly with an increase in the level of SO$_2$ in the air (142.85 to 571.43 $\mu$g m$^{-3}$). Poor nutritional status, in the plants, exposed to SO$_2$, due to altered physiology, was further reflected in the characteristics determining reproductive growth and the seed yield, at harvest. The values for all the parameters, determining seed yield, decreased linearly with the elevation in SO$_2$ concentration (Tables 9-10 and 39-40). The other crops which responded, in a comparable way, to SO$_2$ included soybean (Sprugel et al., 1980). Phaseolus sp. (Saxe, 1983a), lentil and
chickpea (Singh 1989), *Medicago* sp. (Murray and Wilson, 1991),
cucumber (Pasha, 1991), tomato (Khan and Khan, 1993) and blackgram
(Kulshreshtha, 1995). The other related factors which might have
contributed significantly in reducing the seed yield, under the influence
of SO$_2$, might have been the pre-mature loss of flowers (Gupta and
Ghouse, 1987) and/or limited pollen viability with restricted growth of
pollen tube resulting in the failure of fertilization (Linzon, 1978; Bosac
*et al.*, 1993), thus limiting the seed setting (Tables 10 and 40).

Various cultivars of both the crops, rapeseed and sunflower,
differed significantly from each other, in their response to SO$_2$ (Tables
2-10 and 31-40). The variety TL-85 of rapeseed and Morden of
sunflower had maximum values for most of the parameters, may be
because of some varied level of resistance provided by the cultivars to
the pollutant (SO$_2$). This differential behaviour, may largely be
attributed to their genetic make up which is positively different from
each other.

The plants are exposed to various pathogens whose intensity of
infection depends on various factors, borned within and outside the
host. However, under the stress, generated by SO$_2$, the fungus and the
plants are expected to interact differently (Heagle, 1973). This view is
also favoured by Khan *et al.* (1991) but negated by Weinstein *et al.*
(1975) and Mc Leod (1988). As usual, the fungus *Alternaria brassicicola*
caused serious damage to the plants of rape seed, decreasing seed yield by about 4.7%. Moreover, the intensity of this
infection increased in the presence of the $SO_2$, even though this pollutant inhibited conidial germination of the fungus (Table 1) like others (Siddiqui and Khan, 1999), in isolation. It resulted in a further decrease of seed yield by about 5%, over the infected control (Table 10), even at the lowest concentration of $SO_2$. The $SO_2$ causes damage to the tissue of the host exposing it as a better site for the fungal attack. Moreover, changed physiological state of the host could have decreased the resistance capacity of the plants to the pathogen. It seems that $SO_2$ increased the inoculum potential of the fungi by acting in a synergistic manner.

5.2 Fly ash

It may be considered as a material not very much different from the common clay because both are rich in oxides of aluminium, silicon, iron, calcium and magnesium. However, coal and its ash (Table 52) are naturally added with variable amounts of various trace elements (cadmium, lead, nickel, chromium, zinc), therefore making it comparable with that of the soil (Page et al. 1983). Keeping in view, the disposal problem of the fly ash and the faster depletion of the reserves of trace elements of the soil, the application of fly ash may help in replenishing their dwindling reserves and maintain soil texture. The ultimate impact of these elements will naturally depend on the state of occurrence of these elements in the fly ash in interaction with natural factors of the soil and the biological system to which they have been applied. The rate of fly ash application, therefore, be fixed by
analyzing these components of the fly ash, since essential elements may impart toxicity in plants if accumulated beyond the critical limits (Ferraiolo et al., 1990). There is great need to evaluate the impact of fly ash on soil characteristics and the plant productivity.

5.2.1 As soil amendment

The use of fly ash amendment in enhancing the soil fertility by improving soil texture (Chang et al., 1989), soil pH (Molliner and Street, 1982; Singh et al., 1994) and water holding capacity (Sharma et al., 1990) has been successfully attempted. The addition of fly ash to the sandy loam soil improved its E.C. from 3.25 to 7.64 and its water holding capacity (Table 51).

The results clearly demonstrate the economical gains from the fly ash amendment of the soil but within a limited proportion because large scale application renders soil loose and friable (Page et al., 1979). The growth of the root and that of the shoot (Tables 11-13 and 41-45) of both the crops (rapeseed and sunflower) exhibited a linear increase upto 60% (w/w) of the fly ash but decreased with a further increase in its quantity. Similarly, others (Singh, 1989; Pasha, 1991; Matte and Kene, 1996; Patil et al., 1996; Sugawe et al., 1997; Sahu and Dwivedi, 1999) have made recommendations with regard to the use of fly ash in enhancing the soil fertility and crop production. Furr et al. (1978) have, moreover, suggested that the uptake of the elements by the plants was proportional to the rate of ash application. In such cases, the fly ash corrects the nutrient balance in the soil (Hill and Lamp,
and/or pH adjustment (Martens and Beham, 1976). The fly ash from Kasimpur Thermal Power Plant, Aligarh, used in the present study, possessed a rich quantity of some important nutrients (Pasha, 1991 and Table 51). Fly ash being a rich source of most of the required elements (Plank et al., 1975), except nitrogen (Khan and Khan, 1996; Sahu and Dwivedi, 1999 and Table 51) makes them readily available, to the roots, in required quantities, activating plant metabolism with increased synthesis of pigments (Khan and Khan, 1996 and Tables 14-15 and 44-45) and general growth (Fernandes and Henriques, 1990). However, this favourable effect of the fly ash could be gained up to a certain level, which in our case is 60% (Tables 19 and 50), 25% (Saxena et al., 1998) and 50% (Sahu and Dwivedi, 1999) possibly determined by the plant type and the soil environment (Basta and Tabatabai, 1992). A cumulative effect of improved metabolism and growth was further evident on the characteristics of reproductive growth and the seed yield in the rapeseed (Tables 18-19) and sunflower (Tables 48-50) at harvest. Similarly, others (Singh, 1989; Pasha, 1991; Jahan, 1993; Kulshreshtha, 1995; Matte and Kene, 1996; Sugawe et al., 1997; Sahu and Dwivedi, 1999) reported an increase in seed yield by a limited use of the fly ash with the soil. The higher percentage of oil in rapeseed (Table 19) and sunflower (Table 50) may be attributed to the presence of larger quantities of two important nutrients (calcium and sulphur) in the fly ash, involved in the synthesis of fat, (Ahmad et al., 1978; Patil et al., 1996).
Although essential heavy metals, in the form of micronutrients, are required for plant development and growth, but a slight excessive amount of these metals in the soil may produce effects detrimental to plants (Neufeld and Hermann, 1975). The fly ash is a rich source of these trace elements (Wong and Wong, 1986; Wadge and Hutton, 1987 and Table 50), and a mixture of toxic compounds like dibenzofuran and dibenzo-p-dioxin (Helder et al., 1982; Sawyer et al., 1983). Therefore, the soil amended with the fly ash level, above a certain limit, may compel the plants to absorb and accumulate the heavy metals in a quantity which may become phytotoxic (Mayer, 1981 and Hale et al., 1985). A comparable relationship was noticed between the heavy metal contents in the seeds (Tables 20 and 53) and the fly ash (Table 52). However, at the highest level of the metals in the seeds, the values are below the permissible limits but are quite safe at 60% fly ash level where the plants develop no toxic effects and have luxuriant growth and seed production (Tables 19 and 50). Moreover, the presence of a sufficient quantity of chloride, carbonate and bicarbonate ions in the fly ash (Pasha, 1991 and Table 51) shield the plants from the toxic effects of heavy metals by increasing soil pH (Sahu and Dwivedi, 1999).

The varieties of both crops (rapeseed and sunflower) differed significantly in their response to the amendment of the soil with fly ash. T-7 of rapeseed and Morden of sunflower gave maximum response to the treatment where the fly ash level, 40 and 60% proved best. Genetic variations between the cultivars may have largely contributed
in this diversity (Tables 11-19 and 41-50) which is also supported by Basta and Tabatabai (1992).

It may be derived from the body of the Tables 11 to 19 that the rapeseed plants, infected with *Alternaria brassicicola*, had poor growth and seed yield, as compared with healthy plants. However, the diseased plants, grown in the fly ash amended soil, had a significant resistance and could overcome the ill effect of the fungus. The values for most of the parameters, including seed yield increased, over the infected control, with an increase in the fly ash level upto 60% and the values were very close to those of the healthy plants. It gives an impression that the stress caused by the fungal infection is some how overcome by the strength provided to the host by the sufficient quantity of the trace elements in association with the higher metabolic state of the plants, particularly in the cultivar, T-7.

5.2.2 Fly ash dusting

The combustion of coal releases, through the exhaust, finally divided particles of ash (0.1 to 100 μm) entrained with gases. This ash is fairly a stable pollutant and gets deposited on the surface of the materials and plants (Rao, 1985). The fly ash from Kasimpur Thermal Power Plant was chemically analysed and was found to be a rich source of improtant mineral elements and certain heavy metals but lacked nitrogen (Helder *et al.*, 1982; Sawyer *et al.*, 1983; Pasha, 1991 and Tables 51-52). A graded quantity of this ash was applied to the leaves of rapeseed and sunflower plants at varied intervals. The plants gave a
positive response with the values for most of the vegetative (Tables 21-23 and 54-56) and reproductive (Tables 28 and 61-62) characteristics showing a linear increase with an increase in the fly ash level up to 5 gm day\(^{-1}\). However, a further increase in the quantity of the ash (8 gm day\(^{-1}\)) had a detrimental effect on the plants. The presence of water soluble substances, mainly minerals, available from the fly ash (Rohrman, 1971) in the vicinity of the cuticle and the stomata are expected to diffuse (Murray, 1984) into the highly metabolically active tissues of the leaves. They will obviously be transported and/or utilized in various metabolic processes, developing healthy plants (Tables 21-23 and 54-56) with increased seed production (Tables 29 and 63).

The application of larger quantities of the fly ash (8 gm day\(^{-1}\)) is very much expected to make available an excessive quantity of these trace elements, in the mesophyll cells, possibly causing phytotoxicity (Aitken and Bell, 1985). The presence of toxic compounds like dibenzofuran and dibenzo-p-dioxin (Helder et al., 1982; Sawyer et al., 1983) in the fly ash must have further aggravated the stress leading to poor growth and productivity in rapeseed (21-23 and 29) and sunflower (54-56 and 63). Moreover, the deposition of a thin layer of fly ash at the stigma of the carpel could have affected the viability and/or germination of the pollen grains leading to a failure of the fertilization and seed setting (Pasha, 1991). It could have also been associated with the shedding effect, checking the solar radiation reaching to the tissue (Czaja, 1962; Rao, 1985), thereby slowing down the rate of photosynthesis (Singh and Yunus, 2000) and an increase in the
temperature of the plant surface (Mark, 1963; Rao, 1971).

It was possibly the varied genetic make up of different cultivars of rapeseed and sunflower which made them to respond differently to the dusting treatment of the fly ash. T-7 of the former and Morden of the latter had maximum values of almost all the vegetative (Tables 21-23 and 54-56), reproductive (Tables 28 and 61-62) characteristics and seed yield (Tables 29 and 63) with improved oil contents (Tables 29 and 63).

The damage, in terms of reduced growth and yield, to the rapeseed by *Alternaria brassicicola* could partially be recovered by dusting the plants with a low dose of the fly ash. The values for most of the characteristics in the infected plants increased marginally by the application of fly ash up to a level of 5 gm day\(^{-1}\) but were in no way comparable with those of the control, uninfected plants (Tables 21 to 29). The fungi in association with 8 gm day\(^{-1}\) of fly ash proved detrimental for plant growth and productivity.

5.3 Conclusions

On the basis of the results obtained, following conclusions may be drawn.

1. The exposure of the plants of rapeseed and sunflower to SO\(_2\) significantly decreased leaf chlorophyll, nitrogen, phosphorus and potassium contents, all the growth and yield characteristics and seed yield, at harvest. However, the level of sulphur in the leaves increased.
2. Among the cultivars, TL-85 of rapeseed and Morden of sunflower possessed maximum values for all the characteristics, possibly expressing a slight degree of resistance to SO$_2$.

3. The per cent loss increased with an increase in the concentration of SO$_2$.

4. As compared with the healthy plants of rapeseed, those infected with *Alternaria brassicicola* were affected to a greater extent by SO$_2$.

5. The plants of rapeseed and sunflower grown in the sandy loam soil amended with fly ash were taller and possessed more fresh and dry weight of shoot and root, leaf chlorophyll, carotenoids, phosphorus and potassium contents and seed yield, at harvest, as compared with those raised in its absence. The level of all these parameters increased with an increase in the contents of fly ash upto 40% (w/w) and getting stabilized upto 60% but decreased with a further increase in the ash. Moreover, the per cent nitrogen content of the leaf decreased.

6. The fly ash exhibited significant impact even on the rapeseed plants infected (diseased) with *A. brassicicola*. The values for all the characteristics, were comparable with those of the uninfected (healthy) plants, raised without fly ash.

7. The best response of the fly ash addition to the soil was given by the cultivars, T-7 of rapeseed and Morden of sunflower.
8. The seeds produced by the plants developed in the fly ash amended soil possessed a higher quantity of the heavy metals than the control (only soil). However, the level of all the elements was under the permissible limits/safe for consumption.

9. The application of fly ash to the foliage of rapeseed and sunflower plants proved fruitful upto a level of 5 gm day⁻¹, above which it proved to be injurious. The values for the length, fresh and dry weight of the shoot and the root, leaf chlorophyll, carotenoid, phosphorus and potassium contents and seed yield, at harvest, were higher than the control.

10. The diseased plants exhibited a negative impact with the fly ash dusting and the values decreased significantly below that of the healthy control.

11. The plants of rapeseed and sunflower dusted with fly ash produced the seeds with a larger quantity of heavy metals but the values were below the toxic limits.

12. Like the other treatments, T-7 of rapeseed and Morden of sunflower gave maximum response to the fly ash dusting.