Discussion
DISCUSSION

Fly ash is a major particulate air pollutant, released after combustion of coal at very high temperature, 1200-1400°C in thermal power plants, furnaces and other industries where coal is used as fuel. Incorporation of fly ash in agricultural fields for improvement of crop is a very recent idea. Some studies and data available indicate that it can serve as a fertilizer, as it enhances plant growth and productivity (Sikka and Kansal, 1995; Wong and Wong, 1989; Kalra et al., 1998). A number of crops are being examined for their responses to fly ash in relation to growth and productivity and tolerance of fly ash levels in soil. Heavy metals present in fly ash, their accumulation in soil and plant parts are also being examined (Sims et al., 1995; Wong and Su, 1997; Karpate and Chaudhary, 1997). Soil characteristics and the changes brought about by the application of different levels of fly ash in soil have also attracted attention of investigators. An effort in this direction was made in the present study. The data revealed that fly ash addition decreased the moisture content of air dried soil and bulk density. The decreases were inversely proportional to the levels, the decrease in moisture content of air dried soil was either might be due to lack of
particles in fly ash that were endowed with adsorption capacity, or it lacked colloidal sized particles of their mineralogical nature that very few electric charge was burned by them. When fly ash was added to soil it tended to decrease bulk density with respect to increase the level. Similar trend in bulk density reduction in fly ash amended soils was also observed by Van et al. (1988) and Brahmchari et al. (1999). Fly ash addition even at very low (7.5%) level decreased bulk density, increased porosity and the hydraulic conductivity of soil (Shinde et al., 1995). Deposition of fly ash on land, affects the soil properties, because it is enriched with salts and trace elements thus reduces the bulk density of soil and ultimately increases water holding capacity (Hajarnevis and Bhide, 1999). Maximum water holding capacity of clayey soil is advantageous as it increases porosity of soil causing improvement in its drainage (Kene et al., 1991a). In the present study, the fly ash addition in soil significantly increased the water holding capacity, particle density and sticky point (%) while bulk density, moisture content and ignition percentage decreased gradually as fly ash levels were increased, in soil.

In the chemical properties, pH and electrical conductivity were increased gradually as increasing the level of fly ash in soil
in present study. Tripathy and Sahu (1997) also observed increase ment in pH level at 50% fly ash in soil. The pH was also found gradually increased as the levels of fly ash were increased gradually (Brahmachari et al., 1999; Bharti et al., 1999; Page et al., 1979; Menon et al., 1990). The rise in pH depends primarily on soil buffering capacity. The rise in EC might be due to the increasing inorganic constituents in the fly ash. Earlier reports also showed that fly ash addition in soil significantly increased the electrical conductivity by increasing the quality of soluble major and micro nutrients along with the toxic heavy metals released by the ash to soil (Singh et al., 1994; Khan et al., 1996). Eary et al. (1990) reviewed the geochemical factors controlling the mobilization of minor and major elements from fly ash in soil and suggested that the increasing inorganic constituents can raise the electrical conductivity of soil. Present study showed that cation exchange capacity increased up to a certain level i.e. 15%, onward to it a gradual decrease was found. However, decrease in CEC in subsequent levels might be due to podzolanic activity of the fly ash or due to rise in pH (Corey et al., 1981). Improvement in soil CEC due to fly ash addition has also been observed by Deshmukh et al. (2000).
Contents of sulphate, chloride, total carbonate and bicarbonate were increased in all the levels of fly ash in this study. Khan et al. (1997) also found same trend of increase in these contents. Actually these contents are responsible for increasing salinity. These contents are present in sufficient amount in fly ash, as the level of fly ash increased in soil, these contents were also increased consequently the amended soils were saline at very high levels (75 and 100%).

The present study revealed that, nitrogen and organic carbon decreased and phosphorus, potassium increased by increasing the fly ash concentration in soil. From the literatures, it appears that nitrogen is absent in fly ash (Khan et al., 1997; Singh et al., 1997). As a result, increasing the level of fly ash caused deficiency of nitrogen in soils. Bradshaw and Chadwick (1980) also suggested that fly ash contain little to no nitrogen because the nitrogen originally present in coal is volatilized during combustion. Hajarnavis and Bhide (1999) observed that during the combustion process carbon is oxidised into gaseous constituents (CO₂) and thus fly ash generally has a low carbon content. The levels of phosphorus and potassium increased gradually in soils as levels of fly ash increased. This might be
due to presence of these elements in fly ash in high quantity. Similar trends of increase of these elements in fly ash amended soils were observed by Hammermeister et al. (1998) and Khan and Khan (1996).

The heavy metals, which were analysed in this study, were Zn, Mn, Mg, and Pb. These metals were increased by increasing the fly ash in soil. This might be due to the immobilisation of heavy metals as influenced by properties of alkaline soil like higher clay content, cation exchange capacity, higher organic matter, CaCO₃% and soil pH, which are the major factors controlling plant availability of heavy metals (Chanely, 1973). Berman et al. (1999) found the metal contents (Cu, Cd, Zn, Fe, Ni, Cr and Pb) in higher amount in soil amended with fly ash than in the control soil, however, the Cd, Zn, Pb concentrations were either below or within the critical levels. Fly ash generally contains sufficient concentration of essential elements but it is deficient in Mn (Lalson and Adriano, 1990). In the present study also, the fly ash has less amount of Mn as compared to other elements, however, it was in increasing order with respect to the levels.
After harvesting of *B. juncea* and *L. usitatissimum* crops, the values of all the considered parameters of physico-chemical properties in all the concentrations of fly ash in soil were found less in general than before sowing but in a similar trends except pH which was increased in fly ash amended soil after harvesting the crops. These results also corroborate with Satter and Williams (1967), Chang *et al.* (1989) and Sharma *et al.* (1990). The salinity of fly ash amended soil was reduced. This might be due to absorption of salts by the plants. That's why electrical conductivity was also reduced at all the fly ash levels after harvesting than before sowing. The reductions in the values of all the considered parameters might be due to uptake of micro- and macro-elements by the plants. Because for the growth, development and further differentiation of different organs, plants required healthy nutrition and these elements might have provided sufficient as well as healthy nutrition status to growing plants. However, Sikka and Kansal (1995) reported that the available nutrient status of soils after harvest of the rice and wheat crops was not affected by the application of fly ash. This study showed that nutrient status of soils also depends on the type of crop involved in the study. The present study showed that after harvest, the heavy metals concentrations in soil decreased
in all the levels than before sowing. This might be due to uptake of heavy metals (Zn, Mg, Mn & Pb) by plants. The remaining amount of nitrogen and organic carbon, phosphorus and potassium showed decreased values in comparison to the values of these before sowing in a similar trend in general, but at lower levels the values of heavy metals, NPK and organic carbon showed more reduction, this might be due to more absorption of these elements by plants at lower levels of fly ash in soil.

Brick-kiln dust is a second major particulate air pollutant after fly ash in India, emitted from the brick-kilns after complete combustion of fuel (coal + wood) at higher temperature (approx. \(1500^\circ\text{C}\)). The mixture of ash of fuel and dust of bricks after combustion is known as brick-kiln dust. From the literature it appears that a very little work has been done on the smoke released by chimneys of brick-kilns during the combustion of bricks, in relation to agricultural crops (Jain et al., 2001; Sum and Su, 1985). However, no work could be initiated in the past on the incorporation of brick-kiln dust in agricultural fields for improvement of crop. In the present study for the first time brick-kiln dust was incorporated in different amounts with soils.
and their physico-chemical structure were studied in concentrations of 0, 5, 15, 30, 45, 60, 75 and 100%.

The study showed that the physical properties such as water holding capacity, particle density, pore space (%), saturation percentage and sticky point were increased gradually as the level of brick-kiln dust increased in the soil while bulk density, moisture content and ignition percentage decreased with the increasing levels (Table 4). These properties of soil were changed by the addition of brick-kiln dust, this might be due to increase in the porosity because dust contains mostly sand particles which are used during the preparation of raw bricks and are removed after drying and combustion.

The chemical properties, pH and electrical conductivity increased as increasing brick-kiln dust level in soil. This might be due to increase in alkalinity brought about by the addition of brick-kiln dust. The contents of sulphate, chloride and total carbonate and bicarbonate increased gradually, this might be due to gradual increase in EC levels. The decrease in amount of nitrogen and organic carbon by addition of brick-kiln dust was due to volatilization of these contents during combustion of coal. Similar results were observed by Hajarnevis and Bhide (1999)
and Bradshaw and Chadwick (1980). Phosphorus, potassium and heavy metals i.e. Pb, Mg, Mn and Zn were gradually increased because brick-kiln dust possesses more quantity of these elements (Table 5).

After harvesting of *B. juncea* and *L. usitatissimum* crops, the physical properties i.e. water holding capacity, bulk density, particle density, pore space (%), saturation percentage of brick-kiln dust amended soil showed the similar trends in reductions in the values of these properties as in case of fly ash amended soils. These values became less in respective parameters as compared to before sowing. This may be due to absorption of micro- and macro-nutrient elements and heavy metals. The reduction in physical properties was more in soils grown with *B. juncea* crops than *L. usitatissimum* grown soil. The difference was perhaps due to variable genetic makeup of crops. However, the brick-kiln dust possessed more values in physical properties than the fly ash in general, might be due to modification in texture of the soils.

The chemical properties (pH, electrical conductivity, cation exchange capacity, contents of sulphate and chloride and total carbonate, bicarbonate) in the brick-kiln dust amended soil after
harvesting the crops were decreased in similar fashion like in soil samples before sowing in all levels. All properties were less in the amended soil after harvesting than in the soil samples before sowing except pH which was increased after harvesting, might be due to increase in the hydrogen ion concentration, consequently increasing the salinity. However, after cropping, all the considered chemical properties were decreased except pH. These results also corroborate with Salter and Williams (1967); Chang et al., (1989); Sharma et al., (1990). When these parameters were compared cropwise, these parameters were higher in the amended soil samples grown with L. usitatissimum than the B. juncea in general.

After harvesting the crops, the N,P,K, organic carbon and heavy metals (Pb, Mg, Mn, Zn) were also decreased as compared to before sowing. This may be due to absorption of these contents by the roots of plants. The absorption was higher in B.juncea than L.usitatissimum crop, may be due to its different genetic makeup.

Earlier a large number of crops like tomato, okra, eggplant, cucumber, pea, soybean, corn, lentil, chickpea, wheat, rice, bottle gourd, sunflower, groundnut, potato, etc. have been
examined to their responses in relation to growth, productivity
and tolerance to different levels of fly ash in soil (Khan and
Khan, 1996; Kulshreshtha, 1995; Singh, 1993; Mishra and
Shukla, 1986; Singh and Singh, 1986a; Singh, 1989; Khan, 1989;
Raghav and Khan, 2002). However, the responses of various
crops were different to different levels of fly ash. From the
literature it appeared that in general 50% or below 50% levels of
fly ash were beneficial for the growth and productivity of plants.
More than 50% levels were found harmful to all the crops
examined so far at any stage. These results showed that the
available nutrients present in fly ash are maximum only at
certain level for a particular plant species. Keeping in view for
the exploitation of growth potential present in fly ash the two
important oil seed crops B. juncea and L. usitatissimum were
examined against eight concentrations i.e. 0, 5, 15, 30, 45, 60,
75 and 100% of fly ash (Tables 14-23). At the same time these
two crops were also evaluated against brick-kiln dust, the second
most common particulate air pollutant and frequently available in
India, taking all previous concentrations (Tables 24-33).

In the present study, the length, fresh and dry weights of
shoot and root; number of flower, siliqua branch, leaves;
seeds/siliqua seed per plant; 100 seed weight; seed yield; phytomass; green area and leaf area were increased apparently upto 60% fly ash levels in general, however, all these parameters of both crops showed maximum increase at 15% fly ash level (Table 14, 15, 19, 20). The growth and productivity parameters of B. juncea were slightly better as compared to L. usitatissimum in all fly ash levels. Pandey et al. (1994) also observed that leaf number, leaf area, flower weight and plant height of sunflower crop were increased in 60 days old plants when fly ash was amended by 0.5Kg fly ash/m². Moderate rates of fly ash application (2-4% w/w) had a beneficial effect on the dry matter yield of Paddy, but a higher level (8% w/w) had a significant depressing effect (Sikka and Kansal, 1995). Srivastava et al. (1995) also observed that lower level of fly ash (10%) gave the greatest root and shoot length, number of leaves, leaf area, root weight, root: shoot ratio and leaf carotenoid and chlorophyll a and b contents of Lactuca sativa crop. Application of fly ash upto 10% in soil had significantly improvement in the growth and yield performance of sunflower crop over control but at 15% level there was downward effect (Kene et al., 1991a). Singh and Singh (1986) found the good results in rice plants at 10 and 20% fly ash level, but 30% led to decrease in yield. Highest dry
matter yield of soyabean was obtained in the treatment receiving 10% (w/w) fly ash (Lal et al., 1996). The better growth and yield of chickpea was obtained at 40% by Siddiqui et al. (2000). Fly ash amended soil with 20% improved the dry matter and yield of collard greens and mustard greens crops (Menon et al., 1990).

In the present study also, the lower level (15%) of fly ash had given better results in all the considered parameters of both crops. This might be due to changes that occurred in structure of fly ash amended soil and presence of sufficient nutrients at this level which was most suitable for the growth of both plants perhaps, due to their specific genetic make-up. In corn and soya bean, Mishra and Shukla (1986) observed that the increased growth response was attributed by the improvement in chemical properties of soil due to addition of fly ash.

In the present study, the photosynthetic pigments chlorophyll a, b, total chlorophyll contents increased gradually upto 60% and carotenoid upto 45% fly ash level in B. juncea crop and upto 45% in L. usitatissimum statistically. However, photosynthetic pigments were maximum at 15% levels of fly ash but these pigments were slightly higher in B. juncea as compared to L. usitatissimum. The photosynthetic pigment rates were also
found high at lower levels of fly ash in chick pea, soybean, pea, tomato, cucumber, lentil etc. (Khan and Khan, 1997; Singh, 1989; Singh, 1993; Pasha, 1990; Khulshreshtha, 1995). The higher levels above 45% were found harmful to photosynthetic contents. Similarly, higher levels also adversely affected the chlorophyll contents in present study. At 15% level the plant produced healthy and more leaves which were darker than leaves of other levels. The photosynthetic activity of plants might have enhanced at this level resulting better growth and productivity, due to high chlorophyll. Kleinkopf et al. (1976) also advocated that any change in efficiency of photosynthetic machinery ultimately affects the amount of photosynthates which steers the growth of the plant. Higher concentrations of substrate salt and trace elements in fly ash generally reduce photosynthesis.

Total protein (soluble and insoluble) in seeds of both the crops increased only upto 15% fly ash level in the present study. However, the amount of protein was higher in B. juncea. Beyond 15% level, there was gradual reduction in proteins. Low protein contents and reduced nitrate reductase activity were also recorded by Gupta et al. (2000). Hemalatha et al. (1997) suggested that the reduced soluble proteins in agriculture crops
were due to heavy metals. The amount of total protein is based on the availability of nitrogen in plants. The amount of total nitrogen was negligible in fly ash amended soil (Tables 5, 7). Beyond 30% the level of N was almost nil (Tables 18, 23). Therefore amount of total nitrogen and total protein showed the same type of trend.

From the present study, it appears that NPK levels in leaves were found to be maximum at 15% fly ash level which might have contributed in better growth of plants. Singh and Singh (1986b) also observed that NPK levels were higher in grain and straw of wheat plants when grown with low level of (20%) fly ash. Application of 30% fly ash decreased the contents and uptake of NPK. Increasing levels of fly ash caused the deficiency of nitrogen in soil, which led to reduction in growth, and productivity of tomato plants (Khan et al., 1997). However, application of fly ash 10t ha⁻¹ recorded the highest content and uptake of NPK over 5 and 15t ha⁻¹ fly ash (Bhaisare et al., 2000). These studies show that uptake of elements depend upon the type of plant species involved. Phosphorus decreased greatly in leaves of both crops in the present study, which might have caused deficiency of nitrogen and phosphorus in soil and this would
have contributed towards the poor growth and yield of plants at higher levels.

High oil properties in the seeds of both crops in this study were upto 60% maximum being at 15% level (Tables 17, 22). This might be due to availability of sulphur and nitrogen present in fly ash maximum at 15% level. Patil et al. (1996) suggested that improvement in oil content of oilseed crop was due to presence of calcium and sulphur in fly ash.

Among heavy metals in seeds the level of Pb was continuously increased that might be one of the causes of decreasing the all parameters above 15% level. However, other heavy metals Mg, Mn, Zn were maximum at 15% level. These elements were also utilized by the plants as nutrients in low amount. That's why these heavy metals were also decreased in subsequent levels in soil after harvesting the crops but increased in plants (Tables 18, 23) and played as role of toxicants and later became one of the cause of reductions in parameters at higher levels in both the crops.

In this study, an effort for the first time was made to examine the growth promoting potentials of different level of brick-kiln dust in soil on B. juncea and L. usitatissimum. The
length, fresh and dry weights of shoot and root; number of flowers, branch, leaves; seeds/ siliqua seeds/plant; 100 seed weight; seed yield; phytomass; green area and leaf area were increased up to 75% brick-kiln dust levels but maximum being at 45% level for both crops (Tables 24, 25, 29, 30). While these parameters were found to be best at 15% concentration of fly ash amended soil for both crops. This may be due to proper nutrition that was available to the plants at 15% level in fly ash and 45% in brick-kiln dust level (Tables 14, 15, 19, 20). The photosynthetic pigments and oil properties also showed maximum values at 45% level in both the crops but total protein was found better at 30% level in both the crops (Table 26, 27, 31, 32). This might be due to availability of nitrogen in proper amount was up to this level. The elements P, K, Zn, Mg, Mn & Pb gradually increased at all the levels in brick-kiln dust amended soil before sowing but these elements decreased at 45% level in brick-kiln dust amended soil after harvesting of both crops perhaps, the level was most suitable might be due to proper availability of these elements and others which were not analysed here. Although the growth of the plant increased in subsequent level too as compared to control but less than 45% level, might be due to more absorption of heavy metals which slowly retarded the
growth in subsequent levels. The 100% level was harmful for all the parameters.

From the discussion it appeared that the 15% fly ash and 45% brick-kiln dust levels were better for both the crops. While subsequent levels were harmful as all parameters were decreased slowly. While higher concentration 75 and 100% of fly ash and 100% of brick-kiln dust were completely harmful for both crops. Above observations showed that fly ash is better than brick-kiln dust. Because lower dose (15%) of fly ash, giving the best results as compared to 45% level of brick-kiln dust. When both crops were compared it was found that the performance of *B. juncea* was slightly better than *L. usitatissimum*. Since these two waste products are the particulate air pollutants but recently besides the other uses fly ash is used as a non-conventional fertilizer. In the present study, brick-kiln dust was tested to observe the growth potential if present. However, both the waste products were found good for both oilseed crops but at different levels therefore, these two wastes can be recommended for improving any agricultural crop but before recommendation the crops should be tested against their doses. This way disposal problem of these pollutants will also be solved and thus the environment will be free from these particulate pollutants.