Review of Literature
## CONTENTS

### REVIEW OF LITERATURE

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Effect of industrial wastewater on crop plants</td>
<td>4</td>
</tr>
<tr>
<td>2.2</td>
<td>Effect of fly ash on crop plants</td>
<td>19</td>
</tr>
<tr>
<td>2.3</td>
<td>Effect of NPK on chickpea (<em>Cicer arietinum</em> L.)</td>
<td>31</td>
</tr>
</tbody>
</table>
2.1 Industrial wastewater on crop plants

Rapid industrialization in India, during the last few decades, in the form of chemical, dairy, pharmaceutical, mining, distillery, fertilizer, paper and pulp, petrochemical, textile, sugar, machinery, vehicle, food processing, tannery factories in addition to coal fired thermal power plants, has burdened the land and resulted in deterioration of air, soil as well as water. However, some of the liquid discharges resulting from these manufacturing and industrial processes are not necessarily harmful, since it has been observed that after proper treatment or dilution, such wastewaters are beneficial at least for agricultural purpose. Thus, judicious use of wastewater may be one of the feasible options to prevent wastewater from being an environmental hazard. In addition, it has been found in number of trials that it can serve as a potential source of some essential and beneficial nutrients. In fact, the utilization of treated wastewater as liquid fertilizer makes sense because (i) it replaces and conserves mineral fertilizer that would otherwise be introduced into the environment (ii) the presence of organic material improves soil structure and (iii) an alternative disposal method could be environmentally damaging, expensive or limited by space. Literature pertaining to the studies on the industrial wastewater in relation to leguminous as well as non-leguminous crops has been reviewed in the following pages.

Srivastava and Sahai (1987) at Gorakhpur performed petriplate as well as pot experiments to investigate the effect of distillery effluents on Cicer arietinum (chickpea). 15 days old seedlings were picked, and the length of root and shoot was recorded. For the study of growth, earthen pots were taken and 250ml of each concentration diluted with tap water was given. In their study percentage of germination and seed germination index (SGI) decreased with increase in concentration and no germination took place in undiluted effluent. Although in 75%, some seeds germinated but the seedlings could not survive beyond 4 days. The maximum root length was recorded at 2.5% while root and shoot lengths and leaf area increased upto 5% but declined at higher concentrations. In addition to the biomass,
net primary productivity, chlorophyll content, reproductive capacity, seed output and seed protein also exhibited progressive increase up to 5%. The pods also appeared earlier in plants grown in 5%. They were of the opinion that the lower concentrations of distillery effluent could be beneficial and can thus be used as liquid fertilizer. Further studies were conducted by Sahai et al. (1985). They evaluated the same effluents on growth behaviour of Phaseolus radiatus (black gram) and in 1987 Sahai and Neelam carried out another experiment to study the effect of distillery effluent mixed with fertilizer factory effluent on black gram and made more or less similar observations.

Mukherjee and Sahai (1988) while taking Cajanus cajan (pigeon pea) further observed that 50% effluent provided optimum conditions for germination, seed germination index, seed output and dry weight. Seedling establishment was 100% up to 50% effluent and shoot length was maximum at 2.5%. During the same year Sahai and Srivastava studied the effect of fertilizer factory effluents on Brassica oleracea Capitata (cabbage) and Brassica oleracea Botrytis (cauliflower). Decrease in germination and speed of germination index with increase in effluent concentration was reported by them, while Neelam and Sahai (1989) performed another study on Vigna radiata (green gram). Respective lengths of root and shoot, plant biomass and N uptake were markedly increased when plants were grown with 10% distillery effluent. Total N in root, stem and leaf increased even up to 30%. Similarly distillery and sugar mill effluents were taken by Srivastava (1996) who reported that some crops showed moderate tolerance and better biomass when irrigated with diluted effluent. On the other hand concentrated effluent showed deleterious effect.

Patra et al. (1989) observed the yield and economics of gram, Brassica compestris (mustard), Triticum aestivum (wheat), Pisum sativum (pea) and cauliflower, in acid soils at Phulbani in Orissa. Crops were irrigated with various concentrations of paper mill sludge. At 0.5%, gram showed maximum response followed by cauliflower, peas and wheat while mustard showed better response under 0.25% concentration. Chaudhary et al. (1989) at Darbhanga also observed the impact of paper mill effluent on Hordeum vulgare (barley) in petriplates and noted gradual decrease in the germination percentage with increase in effluent concentration. This
effluent was also tested by Misra and Behra (1990) at Berhampur during their study on *Oryza sativa* (rice) seedlings. Percent germination, water imbibing capacity, pigment, carbohydrate and protein content showed decreasing trend with increase in effluent concentration and time. Protein content was found to be most sensitive macromolecule affected. Balaram *et al.* (2000) also at Berhampur studied the effect of paper mill, sugar factory and chloro alkali factory effluents and observed degradation of photosynthetic pigment in intact leaves. Similarly Srivastava (1991) at Jabalpur tested paper mill and chloro alkali effluent on *Raphanus sativus* (radish) and *Allium cepa* (onion) and reported that the latter was highly deleterious for germination and early growth performance as compared to former. Agarwal and Chaturvedi (1995) at Faizabad, in a pot experiment, observed the effect of different concentrations of liquid waste discharged from a paper mill on wheat. Chlorophyll ‘a’, ‘b’ and total chlorophyll contents were considerably decreased, and the reduction in chlorophyll was more with increasing concentration and age of the plant.

Baruah and Das (1997) performed a petriplate experiment on similar effluent at Guwahati. They reported that effluent polluted soil caused delay in seed germination and reduction in final germination percentage of rice by 12.5% compared with seeds in unpolluted soil. Also at Guwahati Dutta and Boissya (1997) noted that higher concentration inhibited the germination and growth of seedlings. Rice seed collected from effluent affected area were less viable and even the viable seeds showed delay in germination. Again Baruah and Das (1998) performed a petriplate experiment and noted delay, retardation and decline in germination and seedling growth under paper mill effluent. Similarly Dutta and Boissya (1999a, b) revealed that NPK contents of rice from paper mill effluent affected areas showed significant differences in growth and productivity. The effluents were further tested and it was observed that chlorophyll content and leaf area could not be directly correlated with both affected and control rice plants. Dutta and Boissya (2000) also reported that the effluent significantly reduced each of the studied yield parameters, when compared to rice plant grown in areas beyond the reach of paper mill effluent. Dutta (1999) also tested paper mill effluent at Nagaon and reported that water that mixed with effluent was harmful to the growing paddy plants in general and injurious to the standing...
paddy crop in particular. In a petriplate study by Sundaramoorthy and Kunjithapatham (2000) on six varieties of groundnut (*Arachis hypogea*) seeds were soaked in 0, 25, 50, 75 and 100% effluent. It was noted that germination percentage, seedling growth and dry weight decreased with increasing concentration. Ready and Borse (2001) at Pravarnagar also carried out a petriplate experiment on *Trigonella foenum-graecum* L. (fenugreek) and reported that at 25% significant increase in germination percentage and other growth parameters was observed. Further increase in effluent concentration decreased the observed parameters.

Agarwal and Gupta (1992) while investigating the effect of nitrogenous fertilizer factory effluent on seedling growth and biochemical properties of chickpea and mustard at Kota, reported that effluent showed deleterious effect. The inhibitory effect was more on radicle than hypocotyl and the effluent was responsible for significant decrease of pigment concentration in seedlings of their study. Jabeen and Saxena (1990) at Kanpur conducted petriplate as well as pot experiments on pea. 5% of distillery and 2.5% of fertilizer factory effluent proved favourable and thus exhibited an increase in dry matter, pigment content and protein content. In their opinion both the effluents could be favourably used for irrigation after proper dilution.

Goswami and Naik (1992) at Raipur, investigated the effect of fertilizer factory effluent on *Cyamopsis tetragonoloba* Taub. (cluster bean). Chlorophyll content improved under 10% effluent, but higher concentration adversely affected it. At the same place earlier Sharma et al. (1990) performed a pot as well as field experiments to study the effect of steel plant wastewater on some crops. Wastewater was applied to *Linum usitatissimum* (linseed) in the field and to *Sesamum indicum* (sesame) and *Phaseolus vulgaris* (frenchbean) in pots. The plants showed decrease in Ca and Mg and increase in P concentrations. Fe was decreased in sesame and french bean but increased in linseed. They were of the opinion that the steel plant effluent should not be used for irrigation.

Subramani et al. (1998) at Annamalai nagar investigated the impact of fertilizer factory effluent on cowpea (*Vigna unguiculata* L. Walp.). In their observation, 10% effluent was beneficial for overall growth. Earlier in 1995 Subramani et al. performed a petriplate experiment on green gram. Hyacinth
Eichhornia crassipes mort. Solms) plants were grown for 5 days in raw distillery effluent to get biologically treated effluent. Green gram seedlings were watered with various concentrations of raw as well as treated effluent. Seedlings at 5% and 10% concentration of biologically treated effluent showed increase in all growth parameters. Subramani et al. (1995) performed another petriplate experiment and reported decrease in germination, growth, yield and productivity of green gram with increasing distillery effluent concentration. In 1999, they further studied the growth behaviour of Ceratophyllum demersum L. (hornwort). Plants were grown for five days and reported that biologically treated effluent promoted the growth and yield.

At the same place Sundaramoorthy et al. (2000) conducted a petriplate experiment to study the impact of fertilizer factory effluent on green gram, black gram, groundnut, Glycine max (soybean), paddy and Sorghum vulgare (sorghum). They reported beneficial effect at 10% effluent, beyond which seedling growth decreased. They conducted another petriplate experiment on groundnut varieties and reported that germination percentage and seedling growth increased with 1 to 10% effluent. The same crop was tested by Sundaramoorthy and Lakshmi (2000) under tannery effluent. Among the various varieties studied, TMV-4 showed better performance under tannery effluent and it proved to be tolerant while variety VRI-4 proved susceptible.

Srivastava and Pandey (1999) at Faizabad, while considering the effect of fertilizer factory effluent, reported significant reduction in total chlorophyll content and biomass of some aquatic mesophytes. At the same place earlier Khan and Srivastava (1996) conducted a field trial to assess the suitability of distillery effluent in agriculture. Field was filled with effluent prior to sowing. After 20 days field was tilled, crops were grown and subsequent irrigation was made with fresh water. After observing the results, they recommended two to three diluted distillery effluent irrigations. The same source of effluent was also tested by Ahmad et al. (2000) at Rawalpindi (Pakistan) on wheat, barley, pea, spinach, fenugreek, Coriandrum sativum (coriander), cabbage and Brassica rapa (turnip). They suggested remedial measures for the hazardous pollutants after observing the effect of effluent on these crops.

At Shillong, Shukla and Moitra (1995) studied the effect of 0, 25, 50, 75 and
100% effluent of integrated steel plant on growth parameters of chickpea, *Phaseolus mungo* (mungbean), maize and rice. They, after observing the results, reported that lower concentrations were beneficial whereas higher showed deleterious effect on germination and seedling growth when seeds were soaked in various concentrations of effluent. Maize showed lowest tolerance to the effluent. Rubber factory effluent was tested by Sharma and Habib (1995) at Bareilly to study the bioaccumulation of Mg, Pb, Cr and Zn in two varieties each of wheat, chickpea, pea, mustard and barley and elemental bioaccumulation, metabolite concentration in component parts of chickpea. Its seeds were sown separately in earthen pots. Ca, K, P, total N, protein and ether extract contents were decreased in all the four component parts of the chickpea i.e. root, stem, leaf and seeds while Na, Fe and carbohydrate content increased. Concentration of sulphate was higher in stem followed by seed, leaf and root. Ash content was higher in the stem of effluent treated cultivar. There was no uniformity in the response exhibited by both the cultivars of all the five rabi crops in the accumulation of Mg, Pb, Cr and Zn in the straw. Earlier in 1990 from the same place, Bahadur and Sharma reported the effect of three effluents of different industries, Indian Turpentine and Rosin Co. Ltd., Western India Match Co. Ltd. and Camphor and Allied Products Ltd. on wheat. Percent germination decreased significantly in the treatment upto sixth day but the decrease was maximum on the first day. The effluent had inhibitory effect on seedling growth. The root and shoot length decreased significantly upto eighth day. Another experiment was conducted by Singh and Singh (1997) to study the effect of turpentine factory effluent and Zn on germination, seedling height, fresh and dry weight, chlorophyll content of *Cajanus cajan* (pigeon pea). Results revealed that higher concentration caused deleterious effect whereas lower had beneficial. Augusthy and Sherin (2001) at Annapuram, performed a petriplate experiment to study the effect of rubber factory effluent on green gram and reported that above 50% effluent retarded germination percentage while upto 50% favoured seedling growth. Length of root and shoot system and number of lateral roots was also increased by low concentration.

Aziz et al. (1996) reported from Aligarh while conducting a field trial at Mathura Oil Refinery on wheat, triticale, chickpea, *Lens culinaris* (lentil), pigeon pea
and summer moong. Crop, when irrigated with wastewater showed an increase in seed yield except in summer moong. Aziz et al. (1993a) in a pot experiment on green gram studied the effect of treated Mathura Oil Refinery wastewater on nitrate reductase activity (NRA). A linear increase was noted from 15 to 25 DAS and then the activity decreased. Aziz et al. (1993b) again tested the performance of lentil with N\(_{15}\)P\(_{30}\)K\(_{40}\) and no fertilizer. Treated effluent proved better as compared to ground water. Treated effluent with fertilizer further enhanced growth parameters. Inam et al. (1993) also compared the effect of refinery effluent and ground water on triticale and wheat. No significant difference was noted in percentage of seedling emergence under both waters. Siddiqui et al. (1994) while using the same water studied the response of green gram. It enhanced leaf number, dry weight, seed number and pod number. Effluent with fertilizer proved more effective as compared to ground water for vegetative growth only while it decreased the seed yield. Considering the same source of water, Samiullah et al. (1994) observed enhanced leaf number and dry weight in a field experiment on wheat. Yield characteristics and final yield ha\(^{-1}\) of the crop were also enhanced. Aziz et al. (1994) again tested triticale and wheat and noted beneficial effect. They also performed a field trial in 1995 on four cultivars of wheat and observed beneficial effect on growth and yield but the effluent resulted in lower protein and carbohydrate content of the grain. Aziz et al. (1996) while taking the berseem (Trifolium alexandrium) under N\(_{25}\)P\(_{100}\)K\(_{50}\) and no fertilizer observed enhanced leaf number and dry weight. Treated effluent applied with fertilizer enhanced growth parameters. Aziz et al. (1998) during another study on frequency of irrigation and the productivity of triticale further observed the beneficial effect on growth, yield and quality of grain with increased number of irrigations. In 1999, maize and mustard (Brassica juncea L. Czern & Coss.) were irrigated and higher values for plant height, leaf area, fresh and dry weight and yield in maize and better shoot and root length, leaf number, shoot fresh and dry weight and yield in mustard were obtained. Effect of wastewater on protein and carbohydrate contents of maize seeds was non-significant whereas oil content and oil yield in mustard increased significantly. From the same laboratory, Hayat et al. (2000) also performed a field trial on the effect of refinery effluent on growth, yield and level of heavy metals in the
seeds of mustard as well as in the soil. It enhanced plant growth, fresh and dry weight while yield characteristics did not show significant changes. Irrigation with both waters increased the level of Cr, Zn, Fe and Mn in the seeds but it was more with wastewater. Also at Aligarh but in different laboratory Ajmal and Khan (1983) studied sugar mill effluent on *Phaseolus aureus* (kidney bean) and *Pennisetum typhoides* (millet). Germination was quickest in the control and with 25% effluent. Ajmal *et al.* (1984) also assessed the impact of Glaxo Laboratories (India) Ltd. effluent on kidney bean and *Pennisetum glaucum* (pearl millet). 100% effluent decreased the germination of kidney bean, while pearl millet showed an increase as compared with control. 25% effluent increased growth of kidney bean whereas pearl millet showed better response with 50, 75 and 100% effluent. Ajmal and Khan (1984) while taking wheat and pea with breweries effluent noted 100% germination under 25, 50 and 75% effluent, while it was 80% and 90% for pea and wheat, respectively in 100% effluent. They also tested the suitability of Hindustan Lever Ltd. and its soap splitting unit effluent on pea and mustard in 1984b. In 1985a, they collected textile factory effluent and applied on kidney bean and *Abelmoschus esculentus* (lady’s finger). 50% effluent proved best for both the crops followed by 25, 75 and 100%. Germination was delayed in 100% effluent and it was 90% under 75% effluents. Ajmal and Khan (1985b) also observed the impact of electroplating factory effluent on *Dolochos lablab* (hyacinth bean) and mustard. Delayed germination and retardation of root and shoot length were observed with increasing concentration, while germination was totally inhibited at 1.5% in mustard seeds. Fresh and dry weights of hyacinth bean increased upto 0.2% effluent. The optimum growth of hyacinth bean was observed with 0.1% effluent. They were of the opinion that only very diluted effluents proved favourable for plant growth.

Singh and Bahadur (1995) conducted a petriplate experiment to study the effect of distillery effluent on rice, wheat, black gram, green gram, pigeon pea, lentil, mustard, soybean, maize and chickpea. In 100% concentration no germination was observed while it was normal in 20%, whereas green gram germinated normally in 50%. On the other hand wheat was more sensitive and showed no germination at 50%, while reduced germination in lentil was observed at 50%. Ghosh *et al.* (1999) at
Patna also studied the germination under distillery effluent. It increased at 75% effluent in chickpea and pea and at 50% in mungbean. Distillery effluent was also studied earlier by Goel and Mandavekar (1983) at Karad on clusterbean. Seeds were germinated in pots and watered with 10, 25 and 50% effluent just after the emergence of seedlings. After 20 days, nodule number was equal in all the sets, but after 40 days it increased at 10% effluent while 50% effluent gave the least nodule number. N content was maximum at 50% and minimum in control. They concluded that 10% effluent can be effectively used.

Also on distillery effluent Somashekar et al. (1992) at Bangalore, studied the response of cow pea and fenugreek. Germination, survival percentage, reduction in root and shoot length, vigour index and fresh and dry weight of both the crops decreased with increasing effluent concentration. They also concluded that properly diluted effluents could be used. Similarly, Kannabiram and Pragasam (1993) at Pondicherry taking the same effluent studied black gram. At 2.5% effluent they observed higher germination percentage and seedling growth. Khan and Dhaka (1996) at Ghaziabad, recommended the use of Simbhaoli Sugar Mill and distillery effluent to grow *Saccharum officinarum* (sugar cane), wheat, maize, mustard and pea economically after its proper dilution. Kannan (2001) at Periyakulum Theni, in petriplates also studied the effect of distillery effluent on green gram and millet. 1% effluent gave the highest values for germination percentage, shoot length, root length and vigour index of both the crops. In control seeds exhibited 100% germination while no germination was observed in 100% effluent. Ramana et al. (2002) evaluated the manurial potential of three distillery effluents i.e. raw spent wash (RSW), biomethanated spent wash (BSW) and lagoon sludge (LS) vis-à-vis recommended fertilizers (NPK + farmyard manure) and a control in a field study. The effluents increased total chlorophyll content, crop growth rate, total dry matter, NPK uptake and seed yield, but inhibited nodulation and decreased nitrogen fixation in groundnut. Among the three distillery effluents, BSW produced highest seed yield followed by RSW and LS. However, distillery effluent did not influence protein and oil contents.

Kumawat et al. (2001) at Ujjain, while taking wheat and chickpea and testing in 0, 25, 50, 75 and 100% base and caustic yellow dye effluent noted that higher
effluent concentration decreased the germination, root and shoot length and dry matter production of both the crops while lower concentration (25%) showed marginal increase.

Ramasubramanian et al. (1993) at Sivakasi studied the impact of match and dye industry effluent on growth and metabolism of mungbean. Seeds were soaked for 2 hrs in diluted effluents (10-40% v/v) and grown in sand culture. With increase in concentration germination percentage, seedling growth, plant fresh and dry weight, chlorophyll ‘a’ and ‘b’, leaf soluble protein and in vivo nitrate reductase activity decreased while leaf L-proline increased. It was found that dye industry effluent was more toxic than match industry. Pronmurugan and Jayseelan (1999) at the same place conducted a petriplate experiment to evaluate the effect of fireworks and dye industry effluent on germination and growth of *Typha angustate* (cuttail). Reduction of root and shoot morphology, biomass accumulation of seedlings was observed under higher effluent concentration.

Shukla and Pandey (1991) observed the impact of oxalic acid manufacturing plant wastewater on maize, mungbean and chickpea. At 25%, seed germination of maize, mungbean and chickpea was 86, 32 and 55%, while at 50% it was 52, 12 and 15% respectively but in control it was found to be 100%. 10 day old seedlings of maize, mungbean and chickpea showed decrease in height at 25% and it was found to be 5.1, 0.7 and 2.6cm, respectively as compared to control.

Saha et al. (1994) at Shantiniketan, studied the behaviour of radicle in petriplates. Seeds of rice, mustard, lentil, green gram, chickpea and pea were soaked in carbon black factory and chemical factory effluents. They observed various degrees of phytotoxic symptoms and concluded that effluent caused deleterious effect on growth of radicle.

Chidaunbalan et al. (1996) at Tuticorin performed an experiment to evaluate the effect of chemical industry wastewater on green gram and black gram. 10% effluent proved effective in promoting germination, growth, chlorophyll and protein content. Murty and Raju (1982) At Waltair conducted a study on the effect of alum factory effluents on rice, green gram and mustard. Effluents were collected from Costal Chemicals dried in the laboratory, powdered and made test solutions of 25, 50,
75 and 100%. In rice, at 25 and 50% shoot inhibition was less than root while in green gram shoot inhibition was more than root at 25%. At 25%, root and shoot growth was severely inhibited in mustard. Further inhibition of shoot growth and total inhibition of radicle emergence was observed in rice at 75 and 100%. Total inhibition of shoot and further reduction in root growth was noticed in green gram. In case of mustard, further reduction in growth of shoot and root was recorded at 50%, but complete inhibition of shoot and further reduction in root growth was observed at 75 and 100%.

Balashouri and Prameeladevi (1994) tested tannery effluent on pigeon pea and sorghum. At 10% legume showed an optimum increase in seed germination, seedling growth, chlorophyll content and biomass whereas sorghum showed better response at 5% effluent. Similarly, Karunyal et al. (1994) conducted petriplate as well as pot experiments on rice, Acacia holosericea (condelsbrawattele) and Leucaena leucocephala (subabul). Germination was inhibited at 25 and 50% effluent and prevented by 75 and 100%. Some other crops like Gossypium hirsutum (cotton), black gram, cowpea and tomato (Lycopersicon esculentum) were also observed with the same effluent for 10 days and it was noted that leaf area, biomass, chlorophyll and protein contents increased at 25% effluent. Arora and Chauhan (1996) at Agra reported significant reduction in germination percentage, length and total biomass in barley. Bera and Bokaria (1999) reported that 10% effluent did not significantly reduce seed germination in mungbean but in 50%, germination was 64% compared with 96% in control. Early seedling growth, fresh and dry weights were better at 2.5%. Irrespective of concentration, chlorophyll ‘a’, ‘b’ and total chlorophyll decreased in 6 day old seedlings. They concluded that tannery effluent can be utilized as a liquid fertilizer only for certain crops at 2.5% dilution level.

Thukral (1989) at Amritsar, performed a pot experiment to study the effect of tailings water irrigation on the biomass of green gram, cluster bean, millet, wheat, barley and mustard and reported decrease in dry weight of different plant parts and total dry weight. The crop worst affected was mustard in which total plant dry weight and dry weight of the fruits decreased. However, dry weight of the fruits increased by 50% in clusterbean. 25.6% increase in dry weight was also recorded in the spikes of wheat. It was concluded that regular irrigation with tailings water retarded the growth
of crop plants.

Trivedi and Kirpekar (1991) at Karad carried out an experiment on soybean and mungbean. Dairy waste increased the ash, Ca, N and P content of both the crops. In case of soybean, P content increased in 10%, 25% and 50% but decreased in 100% effluent. At Bhavnagar also dairy effluent was tested by Prasanna et al. (1997) in a petriplate experiment conducted on green gram and black gram. Only under 25% effluent germination percentage, seedling growth and pigment content were increased while increasing concentration proved deleterious. Earlier Pathak et al. (1992) at the same place utilized pre-treated effluent of manufacturing plant of Excel India Ltd. for raising agroforestry. Subabul was found to grow well on soil being irrigated by the effluent. Srikantha (1998) at Bangalore conducted a pot experiment on dairy effluent on french bean and Amaranthus (amaranthus). Germination decreased with increase in concentration. Dry matter yield of both the crops was recorded highest in control and lowest in undiluted effluent. Uptake of plant nutrients decreased with increase in effluent concentration as compared to control. Heaton et al. (2002) evaluated the influence of two rates of dairy pond effluent application on spatial root distribution of Salix viminalis PN386 (common osier) and NZ1295 and Eucalyptus nitens (shining gum). It was found that spatial distribution was influenced by effluent rate, with greater quantities of both fine and coarse roots in the top soil horizons with the higher effluent rate of 300 m$^3$ ha$^{-1}$ compared to 150 m$^3$ ha$^{-1}$.

Gupta and Nathawat (1992) at Jaipur, took various concentrations of textile effluent and the effect on germination and seedling growth of pea was observed. Effluent exerted toxic effect on seed germination and seedling growth. Root and shoot length and biomass decreased with increasing concentration. But root was adversely affected than shoot. Earlier using the similar effluent in 1988 Annon at Naroda, performed a field experiment for the successful cultivation of jawar, Pennisetum americanum (bajra), okra, tomato and chilly (Capsicum annum). On the same lines Singh et al. (2001) at Jodhpur suggested that some forest tree species can be established successfully using textile industrial wastewater in arid region.

Vijayakumari et al. (1993) at Coimbatore evaluated the effect of soap factory effluent on pearl millet Stapf Hubbard, finger millet (Eleusive coralana L. Goertn.),
green gram and black gram. Seeds were soaked in petriplates and after 24hrs, the imbibed seeds were allowed to germinate on germination towel. At 100%, germination percentage and growth of shoot, root and lateral roots were decreased in both pearl millet and finger millet whereas in pulses seed germination and seedling growth were totally suppressed. Upto 5%, cereals showed an increase in seedling growth but the pulses have registered maximum growth when treated with 2.5% dilution.

Srivastava et al. (1995) at Jabalpur, investigated the effect of ordinance factory effluent on pea. It was highly deleterious for the germination and early growth. The deleterious effect was increased with increasing concentration.

Jabeen and Abraham (1997) at Thiruvanthapuram, in petriplates, noted the effect of Hindustan News Print Factory effluents on seed germination and seedling growth in Cassia tora (foetid), Cassia roccidntalis (coffeeweed) Vicia faba (bakla) and cowpea. The effluent caused stimulatory effect in most of the parameters studied. Adverse effect on germination and seedling growth were negligible. Klimakhin et al. (1998) in a separate study conducted in petriplates and pot to evaluate the effect of sugar factory effluent on wheat, oat, lucerne (Medicago sativa), pea and sugar beat (Beta vulgaris). It was found that germination energy and germination capacity were in all cases equal or slightly superior to that of control. But in pot experiment, the effluent had beneficial effect on plant growth and development. Tiwari and Tripathy (2001) also noted the effect of Balrampur Chinni Mill’s effluent on pea var. Asanji and Arkel. In the control, 100% seed germination was achieved on 6th day while seeds treated with 25% effluent showed 95% and 85% germination in Arkel and Asanji respectively on 7th day. Maximum inhibition was observed at 100% effluent in both varieties. Kumar (2000) at Madhubani, conducted an experiment to study the influence of periodic watering with Chakia Sugar Mill’s effluent on polygenically controlled characters of barley. Results revealed that each parameter was reduced when irrigated with effluent.

Abasheeva and Revenskii (1992) at Uan-Ude (Russia) conducted a pot experiment to study the impact of selegensky cellulose and cardboard mill effluents on productivity and chemical composition of Oat, rape (Brassica napus) and pea. Crops
were grown in pots containing alluvial meadow or grey forest soil and irrigated with clean water or purified wastewater. The wastewater increased dry matter yield of oats on both soils whereas dry matter yield of pea on grey forest soil and did not affect those of rape on either soil or pea on alluvial meadow soil. There were no adverse effects on chemical composition or food value of crops.

Karpate and Choudhary (1997) at Nagpur, performed an experiment to study the impact of thermal power plant waste on wheat. The crop was grown in fly ash amended soil (50, 70 and 90%) and irrigated with various concentrations of fly ash water i.e. 25, 50, 75 and 100%. At lower concentrations the fly ash water and fly ash had stimulatory effect on crop, while higher concentrations showed deleterious effect.

Das et al. (2000) at Dhanbad, conducted a petriplate experiment to evaluate the effect of Chadrapur Power Plant’s fly ash pond effluent on peas and Vicia sativa (common vetch). At 25% effluent the germination rate was stimulated in both legumes. But at 50%, only 0.5% enhancement was noticed in pea. Shoot growth was promoted upto 50% in both the crops. Maximum growth index was recorded with 50% effluent. It was concluded that diluted effluent may be used for better plant growth. Shetty and Somashekar (2000) studied the germination and growth of kidney bean when irrigated with effluent of Bharat Heavy Electricals and reported that diluted effluent showed better percentage germination, growth and chlorophyll content. At 75-100% concentration drastic reduction was noticed. The effluent contained several plant nutrients and therefore, as pointed out by them, could be recommended for irrigation at lower concentrations.

Crowe et al. (2002) at Alberta (Canada) studied the effect of major oil and industrial companies released consolidated tails (CT) water on plant colonization and germination and post-germination growth of some terrestrial and aquatic plants. To check viable options for reclamation hummock-wetland system had been constructed, in addition, natural wetlands had been established as a result of seeping of the effluents. Vegetation surveys revealed that constructed wetlands and consolidated tails had low biodiversity and were not invaded by many aquatic plants. Effluent had an inhibitory effect on germination of tomato, clover (Trifolium pratiferum), wheat, rye (Secale cereal), pea, reed canary grass (Phalaris arunadinacea) and loblolly pine.
**Review of Literature**

(*Pinus taeda*). Effluents from constructed wetland and CT were responsible for delay in germination and reduction in fresh weight of seedling of tomato, wheat, clover and loblolly pine.

Stehlik (1986) at Harlickuv Brad (formerly Czechoslovakia) studied the seedling growth of *Sinapsis alba* (white mustard) irrigated with brewing starch factory and canning factory effluents and reported that starch wastewater was found to be usable after dilution, while distillery wastewater showed adverse results even if diluted. Again in 1987 he performed a petriplate as well as pot experiments to investigate the effect of yeast plant wastewater on white mustard and found that undiluted wastewater had little or no inhibitory effect on germination, whereas separate fractions of wastewater reduced germination. Dry and fresh yields of pot grown plants were increased by wastewater.

Baumgartel and Fricke (2000) at Hanover (Germany) performed a field trial to monitor soil N levels and uptake of N and K by winter rape (*Brassica napus* biennis) cover and catch crops after the application of wastewater from starch potato processing factories in late summer. They concluded that wastewater may be used as liquid fertilizer.

Sundari and Kanakarani (2001) at Kodaikanal assessed the impact of pulp unit wastewater. The analysis showed that the partially treated effluent had adversely affected the soil fertility and crop production. Similarly earlier at Florida (USA) Walsh *et al.* (1991) exposed vascular wetland plants to effluents discharged from a pulp mill in addition to coke plant and wastewater treatment plant. There was no effect of effluent on germination but growth rates were reduced significantly in most cases.

Murillo *et al.* (2000) at Cabrera (Spain) conducted a field experiment to examine the effect of drip irrigation using wastewater from olive industry. Wastewater caused decrease in leaf water potential, stomatal conductance to H₂O and the photosynthetic rate in olive trees, after 15 days of irrigation. Wastewater significantly reduced olive yield as compared to control. Sedykh and Tarakanov (2000) performed a petriplate experiment to study the effect of oil and gas drilling waste on some woody plants. Results showed that small doses of drilling waste
(below 10%) can stimulate germination and sprouting intensity but doses greater than 20-25% reduced it.

Barman et al. (2001) at Lucknow, reported the impact of electronic component manufacturing unit effluent on soil and plants. Effluent showed higher accumulation of metals in plant parts of water hyacinth and Marsilea sp. (four leafed clover).

In 2000, Salgare and Acharekar studied the effect of industrial pollution on weeds of Kalu river. Industrial pollution of Kalu river inhibited all the parameters studied under growth performance of five weeds. In 1991, also Salgare and Andhyarujina at Mumbai, evaluated the effect of polluted water of Patal ganga on the mineral contents of its bank vegetation. Out of the four species collected Crotolaria retusa (rattle weed) was found to be most sensitive species as it showed maximum inhibition in the mineral contents while Argemone maxicana (prickly poppy) and Leucas aspera (dronapushpi) were found to be more resistant.

Prashanthi and Rao (1998) at Hyderabad, performed a petriplate experiment to evaluate the effect of industrial effluents and polluted water on seed germination of some crops. The effluents and wastewater were found to be unsuitable for irrigation purpose. Again, they (Prashanthi et al., 1999) performed an experiment and reported that germination and dry matter yield of some crops treated with polluted well water and soil were reduced as compared to control.

Dhafer et al. (2000) conducted an experiment to investigate the impact of complementary wastewater irrigation using an infiltration-percolation process on the growth of durum wheat (Triticum durum) and observed an increase in yield.

2.2 Effect of fly ash on crop plants

Coal based thermal power plant stations have been the major source of power generation in India and nearly 15-30% of the total amount of residue generated during coal burning constitutes the fly ash. Its particles when dumped are responsible for serious problems to human and animal health (Page et al., 1979; Borm, 1997) as well as to the higher plants. Impact of fly ash is however, very complex therefore, its assessment has been addressed for both the negative as well as the positive effects on plants. Partly it may be a potential nutrient source if the soil is amended with a limited quantity making it eco-friendly during ecological recycling, whereas its utilisation in
some industrial purposes has also been established (EPD 1993). Unfortunately, the major part of fly ash is disposed off in unmanaged landfills or lagoons, which serve as major source of environmental pollution. To overcome this menace, revegetation trials of fly ash landfills have been conducted involving appropriate blending of fly ash with organic wastes and the application of nitrogen fixing organisms (Cheung et al., 2000; Rai et al., 2000; Vajpayee et al., 2000). It may be pointed out that fly ash is enriched with macro and micro nutrients, which may enhance the plant growth specially under nutrient deficient soils (Plank and Martens, 1974; Martens and Beahm, 1978). However, the main constraint in the use of fly ash is the high alkalinity and its salt contents, which may depress the plant growth and may cause the deterioration of soil (Hodgson and Holliday, 1966). Despite this, variety of vegetables, millets, cereals and trees have been observed to grow successfully in soils amended with fly ash (Lisk et al., 1979; Singh and Singh, 1986; Sikka and Kansal, 1995; Kumar et al., 1996; Khan and Khan, 1996). The review dealing with fly ash effect has been divided into leguminous and non-leguminous crops in the present thesis.

Matte and Kene (1995) conducted a field trial at Nagpur and observed the yield performance of various kharif and rabi crops. Cotton, sorghum, groundnut, soybean, green gram and rice were grown in kharif (monsoon) and wheat, gram and mustard in rabi (winter) season. Crops were given 0-15t fly ash ha$^{-1}$ along with 0, 75 or 100% of recommended rates of NPK fertilizers. Application of 10t fly ash ha$^{-1}$ gave the best results, increasing seed grain yield by 7-30%. In 1997, Kuchanwar et al. also studied the effect of graded doses of fly ash and fertilizers on nutrient content and uptake of groundnut grown with 0, 5, 10 or 15t ha$^{-1}$ along with N$_{25}$P$_{50}$ or N$_{18.75}$P$_{37.50}$. Application of fly ash and N, P fertilizer separately and in combination significantly increased the N, P and Mg contents in plants. The highest N, P, K, Ca and Mg contents were recorded with N$_{25}$P$_{50}$ while highest uptake of all nutrients was observed when 10t fly ash ha$^{-1}$ was applied. During the same year Karpate and Choudhary while working on wheat also reported beneficial role of fly ash when given in lower concentration.

Bhaisare et al. (2000) at Nagpur conducted an experiment on green gram with
the $N_9P_0$, $N_{18.75}P_{37.50}$ and $N_{25}P_{50}$ and reported that highest yield of grain and straw along with highest content and uptake of nutrients, crude protein and test weight were recorded with 10 t ha$^{-1}$ fly ash. Again crop responded well to higher dose of N and P fertilizers for yield, quality, nutrient content and their uptake.

Kalra et al. (1997) at New Delhi conducted a pot experiment to evaluate the effect of fly ash amended soil on germination and stand establishment of wheat, chickpea, mustard and lentil during the winter season and rice and maize during the summer season. The applied fly ash concentrations were 0, 10, 20, 30 and 40% for rabi crops and 0, 5, 10, 15 and 20% for summer season crops. Fly ash amended soil delayed the germination. They also observed that summer season crops were comparatively less sensitive to ash for germination than winter season crops. Among the winter crops, mustard was most affected in terms of germination as well as stand establishment. Again in 1998, they studied the effect of fly ash on growth and yield of wheat, mustard, rice and maize. Fly ash was added @ 5, 10, 15, 20 and 50 t ha$^{-1}$. The seed yield in maize and mustard increased with 10 t ha$^{-1}$ fly ash. On the other hand the yield of wheat increased up to 20 t ha$^{-1}$ and it declined thereafter. In case of paddy yield addition of 10 t ha$^{-1}$ of ash could not increase the seed yield as it was similar to no fly ash.

Barman et al. (1999) at Lucknow, conducted a field experiment with fly ash amended soil. They observed accumulation of heavy metals in turnip, cabbage, Daucus carota (carrot), radish, Spinacea oleracea (spinach), peas, coriander, Lactuca sativum (lettuce), tomato, Solanum melongena (brinjal), chickpea and mustard receiving fly ash of a thermal power plant. In the edible parts Cu, Zn and Pb concentration was within permissible limits, whereas Cd, Cr and Ni was more. At the same place, Srivastava et al. (1995) observed the 10% fly ash amended soil showed a marked increase in plant growth of lettuce while 20 and 30% retarded it.

Some experiments related to fly ash-soil amendment were also carried out at Aligarh to evaluate the impact on various crops. Mention may be made of Khan and Khan (1996) increase in growth, yield, carotenoids and chlorophylls of tomato with 40-80% fly ash, being optimal at 50 or 60%; Khan et al. (2000) beneficial effect for growth, seed germination and metal uptake in pigeonpea, black gram and okra upto
75 g kg\(^{-1}\) soil; Siddiqui \textit{et al.} (2000) who reported increase in various parameters of chickpea under 40\% fly ash; Khan and Abdussalam (2001) beneficial effect of lower and medium concentrations on some ornamental plants; Khan \textit{et al.} (2001) beneficial effect on some physiological parameters at lower doses up to 20-30 g fly ash ha\(^{-1}\) soil in barley and wheat; Ahmad and Khan (2002) increase in fresh and dry weight of pea at 20\% fly ash level, whereas fresh and dry weight of nodules under 20-80\% ash level; Ahmad and Saeed (2002) increase in leaf number, fresh weight plant\(^{-1}\) and total biomass in linseed at 40\% fly ash level; Raghav \textit{et al.} (2003) evaluated the effect of fly ash and ceramic dust as a soil amendment and reported that 20\% fly ash proved better for growth and yield performance in tomato; Singh and Khan (2003) reported the same concentration of fly ash for better growth of mustard cultivars under conditions of induced drought; and Singh and Siddiqui (2003) significant increase in plant growth and yield of rice under 40\% fly ash level.

Elseewi \textit{et al.} (1978) at California (USA) carried out a greenhouse experiment to study the availability of sulfur from fly ash. Two series of experiments were conducted. In first one, fly ash was mixed with soil at the rate of 0, 0.25, 0.50, 1, 2, 4 and 8\% by weight. Sufficient amount of sulfur free-mixed fertilizer was added to each pot at N, P and K rates equivalent to 400, 250 and 300 mg kg\(^{-1}\) for alfalfa and 250, 160 and 200 mg kg\(^{-1}\) for bermudagrass respectively. In the second experiment, fly ash and gypsum were mixed with soil @ 25, 50 and 100 mg S kg\(^{-1}\) soil. N and P were added at the rate of 200 and 100 mg kg\(^{-1}\) and seeds of turnip and white clover were sown in the pots. Fly ash improved S deficiency in the soil and maximized the yield of alfalfa and bermudagrass. The increase in yield was accompanied by an increase in S content of the plant tops from deficiency level to sufficiency level. Significantly the yield and S content of turnip and white clover were equally improved indicating the availability of fly ash derived-S, equivalent to that of gypsum-S.

Aitken and Bell (1985) at St. Lucia Qld. (Australia) studied the uptake and phytotoxicity of B present in fly ash. French bean and Rhodes grass (\textit{Chloris gayer}) in one experiment grown in fly ash-acid washed sand amendment (5 and 10\% by weight) and in another experiment, grown in 0, 15, 30, 70 and 100\% fly ash-sandy loam soil amendment. Water holding capacity of the soil was increased by fly ash,
however, adding large quantity of untreated fly ash resulted in poor plant growth due to boron toxicity. Rhodes grass tolerated higher boron toxicity by absorbing less elements than French bean. In their opinion phytotoxicity of boron could be a major problem in establishing vegetation on ash.

Shukla and Mishra (1986) at Kanpur conducted a petriplate experiment on fly ash extract and studied growth and development of corn and soybean seedlings. In 0.5 to 1.0% fly ash extract, no significant deviation in germination, root and shoot growth, fresh and dry weight and pigment content in both crops was noted. However, higher concentration adversely affected these parameters. The treated seedlings accumulated more amount of elements in the root and shoot. In 1986, Mishra and Shukla they further determined the elemental composition of corn and soybean. 5% fly ash level increased plant height and biomass, while higher concentration proved deleterious. Fly ash showed no change in P, K or Ca content of roots, shoots or seeds, but increased their B, Cu, Mn and Zn content. 25% fly ash level increased B content in roots of both crops.

Srivastava et al. (1995) rehabilitated the fly ash dump yards at Panki Thermal Power Plant, Kanpur by growing six nitrogen fixing and four non-nitrogen fixing tree species. Suitable treatment of fertile soil (50%), FYM (2.0kg) and DAP (150g) was imposed in each pit taking fly ash in a pit as control. Survival percentage, height and diameter were noted every year. Observations during third year under treated conditions revealed that the top performing tree species were subabul Acacia nilotica (acacia), Albizzia lebbek (lebbek) and Pithecellobium duke (kamat siri). The overall best performer under treatment was subabul and without any treatment was acacia. They suggested to rehabilitate fly ash dump yards with nitrogen fixing tree species.

Benes and Mastalka (1987) at Prague (formerly Czechoslovakia) studied the element uptake by plants from soil enriched with power station waste. Bakla, french bean, mustard, pea, barley, cabbage, maize, flax, oats, fodder peas and buck wheat were studied in the laboratory and french bean and barley under the field conditions. They reported that soil with high content of power plant ash was proved unsuitable for crop cultivation.

Menon et al. (1993) at Savannah (USA), investigated the suitability of fly ash
amended compost prepared from grass and amended with fly ash collected from coal fired power plant, as a manure for mustard, collard greens, string bean, bell pepper and eggplant grown on three compositions namely, soil alone, soil amended with composted grass clippings, and soil amended with mixed compost of grass clippings together with 20% fly ash. The fly ash amended compost enhanced dry matter yield of collard greens and mustard only but string beans, bell pepper and eggplant showed no significant increase.

Dzeletovic and Filipovic (1995) at Zemem (Yugoslavia) studied autumn rye, lucerne, barley and winter rape on power plant ash and bottom slag deposits. According to them with the application of conventional agricultural techniques, good grain seed quality was achieved on various parts of the ash bottom slag deposits. However, it could be achieved with high fertilizer levels given at the rate of $N_{228}P_{90}K_{90}$.

Lal and Mishra (1996) at Ranchi evaluated the effect of fly ash on nodulation in a pot study. Seeds of soybean were inoculated with *Bradyrhizobium japonicum* and grown under 0, 4, 8, 16, 32 or 100% fly ash and 0, 50, or 100% of recommended NPK fertilizer doses. Nodule number was highest with 8% fly ash level, but further increase in fly ash concentration decreased it. However, NPK application increased the nodulation. Nodule dry weight plant$^{-1}$ was highest with 8% fly ash + recommended NPK rate. Lal et al. (1996) also at Ranchi, studied soybean plant, grown in pots containing acid alfisol (pH 4.9) amended with different rates of fly ash. The highest dry matter yield of soybean was obtained at 16% fly ash level and a significant reduction in plant growth was observed at levels higher than 16%.

Khandkar et al. (1996) at Pantnagar while growing rice cv. Jaya soybean cv. PK-327 and black gram cv. Pant U-30 considered a combination of clay loam soil with unweathered coal fly ash as 0, 2, 4, 6, 8, 12, and 20%. Crop yield was increased up to 6% except for soybean at 20%. Straw yield of rice and soybean was increased by 4% fly ash and straw yield of black gram by 6%. According to Patil et al. (1996) application of fly ash @ 20t ha$^{-1}$ resulted in higher yield of sunflower when compared to control at Raichur.

Baskaran et al. (1998) in Tamilnadu conducted a field experiment to observe
the effect of fly ash on rice, greengram, groundnut and brinjal. One crop of groundnut was grown in kharif 1996 under 2.5 and 5 t ha\(^{-1}\) with or without FYM at the rate of 12.5 t ha\(^{-1}\). In addition, two crops of groundnut were grown in summer 97 and kharif 97 at 5 and 10 t ha\(^{-1}\) of fly ash. Rice showed marginal increase in the number of tillers at 10 t ha\(^{-1}\). Green gram and groundnut were not affected adversely in germination, crop stand and nodule number while pod yield was increased under 2.5 t ha\(^{-1}\) fly ash + 12.5 t ha\(^{-1}\) FYM. Slight increase in growth of brinjal was observed at 2.4 t ha\(^{-1}\). Jha et al. (1998) at Dhanbad, carried out a field experiment for biological reclamation of low lying areas and waste lands, by applying fly ash in bulk through afforestation, teak nursery raising and cultivation of crops. Indian rosewood was grown under the scheme of afforestation in Murshidabad. In another experiment teak seeds were sown in plots after proper levelling, ploughing and mixing of fly ash. Growth rate of the plants in the ash filled reclaimed soil was comparatively faster than the plants grown on normal soil. In case of teak, germination rate of seeds, height of seedlings and their collar diameter was higher with increasing dose of fly ash. Tripathi et al. (1998) evaluated its impact in light and shade environment on growth and chemical response of *Albizia procera* (acacia) and *acacia gum*. Seeds were germinated in pots under 10, 20 and 30% fly ash-soil amendment. Lower concentration favoured the growth of both the tree species, however, higher concentration had adverse effects. Sarangi and Mishra (1998) at Burla (Orissa) evaluated the soil amended with 15% fly ash in agriculture as nutrient supplement in groundnut, lady’s finger and radish. Root length, shoot length, biomass, leaf number, total leaf area plant\(^{-1}\) and yield were mostly enhanced in fly ash amended soil.

Vallini et al. (1999) at Verena (Italy), in a pot experiment studied the growth response of bakla with different amendments of coal alkaline fly ash, co-composted fly ash and lignocellulose residues. At the rate of 5 and 10%, in both soils, neither fly ash alone nor co-composted fly ash extracted any negative effect. Plant biomass production was not influenced in either clayey or sandy soil. In a field experiment effect of fly ash-soil amendments on yield and quality of soybean and wheat was studied by Kumar et al. (1999). Fly ash-soil amendment (4-16%) increased the yield of both crops. Application of 50 and 100% NPK showed similar results especially at
higher levels. At the same place they (Kumar et al., 1998) had reported beneficial role on rice, when given in lower concentration. The application of 8% fly ash + recommended NPK rate proved highest grain yielder of 4.85t ha\(^{-1}\) which was not significantly different from 4.63t ha\(^{-1}\) obtained with 4% fly ash + 10t FYM + 50% of the recommended NPK rate.

Das and Jha (2000) evaluated its effect on pigeon pea in petriplates. Seeds were germinated and studied under different concentrations of fly ash in water. There was slight stimulation in plant height and root length at 15-30% while at 45% germination and seedling growth were decreased. KeGong et al. (2000) at Henan (China), studied the effect of magnetized fly ash compound fertilizer. In a field trial, soybean was given 49kg magnetized fly ash compound fertilizer 667m\(^2\). Results indicated the increase in yield which was found to be higher in magnetized fly ash than same amount of NPK fertilizer and with non-magnetised fly ash compound fertilizer. The magnetized fly ash compound fertilizer improved soybean root nodule formation.

Sriramachandrasekharan (2001) at Cuddalore, conducted a filed experiment to study the effect of lignite fly ash (LFA), gypsum, biodigested pressmud (BP), FYM and lignite humic acid (LHA) applied singly or in combination on groundnut. All treatment significantly enhanced pod number, 100 kernel weight, seed and haulm yield, protein content and nutrient uptake. Application of 7.5t BP ha\(^{-1}\) + 1.2t LFA ha\(^{-1}\) + 200kg gypsum ha\(^{-1}\) recorded highest pod number, 100 kernel weight, pod yield, haulm yield, oil and protein content and NPK uptake. Poonkodi (2003) at Annamalai studied the effect of lignite fly ash (LFA) on the performance of groundnut. Four concentrations of LFA were taken and recommended dose of NPK i.e. 17, 34 and 54kg ha\(^{-1}\) was applied basally. Results revealed that 6t LFA ha\(^{-1}\) registered maximum pod yield although it was at par with 5t and 4t LFA ha\(^{-1}\).

While considering the non leguminous crops, Korcak (1985) at Bethville (USA) studied the effect of coal combustion wastes used as lime substitute on nutrient of apple seedlings in three soils. Growth was reduced by 60% on the manor soil amendment with fly ash, applied at twice the lime requirement. Leaf N, P, K, Cu and Al were not significantly affected by treatments while Ca and N decreased.
Singh and Singh (1986) at Varanasi conducted an experiment on rice. Three fertility levels of NPK; low (60, 40, 30kg ha\(^{-1}\)), medium (80, 40, 40kg ha\(^{-1}\)) and high (120, 180, 60kg ha\(^{-1}\)) and four of fly ash (0, 10, 20 and 30%) were tested. Productive tillers, panicle length, test weight, number of grains panicle\(^{-1}\) and filled grains panicle\(^{-1}\) were significantly more in high fertility levels. Seed yield was also maximum in high fertility level which was significantly superior to medium and low fertility levels. 20% fly ash significantly increased the number of productive tillers hill\(^{-1}\), length of panicle, number of grains panicle\(^{-1}\) and test weight and decreased the unfilled grains.

Joseph (1987) in USA studied the growth response of Agrostis tennis var. Highlander (colonial bentgrass), Festuca arundinacea var. Kentucky 31 (fescue), Lespedeza cuneata (sericealespedeza) and soybean var. Brogg on fly ash amended strip mine soils. Seeds were sown in soil, mixed with 70t ha\(^{-1}\) fly ash. Mean biomass production was markedly higher for each species in fly ash treated plots. There was production of numerous and apparently healthy root nodules in case of colonial bentgrass, indicating vigorous nitrogen fixation. Beresniewich and Nowosielski (1987) at Skierniewice (Poland) compared the fertilizing effect of brown coal ash with that of limestone. Upto 20t ha\(^{-1}\) of ash or limestone were applied. Ash increased the vegetables yield.

Wong and Wong (1989) at Kowloon (Hong Kong) studied the germination and seedling growth of Brassica parachinensis (Chinese flowering cabbage), and Brassica chinesis (Chinese cabbage). In sandy soil amended with 3 and 6% fly ash, germination was enhanced, while in sandy soil amended, with 12 or 30% and sandy loam soil with 30% fly ash significant reduction was noted. Dry weight production of crops was enhanced and the length of first leaves, shoot and cotyledons were found to be greater with 30% but reduced with 12 and 30% in both the soil types. In another experiment, they (Wong and Wong, 1990) also evaluated its effect on yield and elemental composition of the two crops which were grown in pots, filled with sandy and sandy loam soil amended with 0, 3, 6, 12 or 30% fly ash. Crop yield was highest at 30% fly ash level, except for Chinese flowering cabbage grown in sandy loam in which yield was highest at 12%. Yield of both the crops was significantly higher in
RevicAV of Literature

sandy loam than in sandy soil. Lau and Wong (2001) also tested the use of weathered coal fly ash, to alleviate the toxicity of manure compost. Addition of lagoon ash at the rate of 5% for immature manure compost and 10% for mature manure compost resulted in higher seed germination rate and root length growth of lettuce. Su and Wong (2002) at the same place, determined the amount of coal fly ash required to stabilize sewage sludge, without causing an adverse effect, on the growth of corn seedlings in a loamy soil receiving the ash-sludge mixtures amendment. Dry weight receiving 1:5 ash sludge : soil mixture (v/v) was significantly higher than 1:1 soil mixing (v/v). The highest yield was obtained at 5 and 10% ash sludge mixture amended soil at 1:5 soil mixing ratio. Nevertheless, the yield at 35% ash-sludge amended loamy soil at 1:1 v/v was still higher than that of soil with fertilizer treatments.

Singh et al. (1994) studied the growth response and element accumulation in fodder pea. 2, 4 and 8% were mixed with soil in 1m² plots and seeds were sown. Low amounts of fly ash proved favourable for plant growth and it improved the yield. However, heavy metal accumulation was higher in plants grown in fly ash amended soil.

Kenneth et al. (1995) at Aiken (USA) performed a green house experiment and evaluated the effect of fly ash/sewage sludge mixtures and application rates on biomass production of jawar. All mixtures of sewage sludge with fly ash generally increased plant growth and yield at 50:100t acre⁻¹ but showed reduction in growth and yield at higher application rates. Mcload and Thomas (1997) also at Aiken studied the differential sensitivity of Nyssa aquatica (water tupelo) and Taxodium distichum (common bald cypress) grown under 0, 2.5, 5 and 10% fly ash-sand amendment. Growth of common bald cypress was not adversely affected by fly ash addition, however, biomass, basal diameter and height of water tupelo were reduced at the two higher fly ash rates. It was found that regeneration of water tupelo would be less successful than common bald cypress in wetlands containing fly ash.

In a pot experiment suitability of fly ash for reducing heavy metal toxicity in maize plants was studied by Shende et al. (1995). They confirmed the suitability of 2% and 5% fly ash to calcareous soil as it showed better plant growth, while beyond
5%, the crop growth was significantly reduced. On the contrary, acidic soil showed positive response to fly ash addition up to 20% but the resulted crop growth was comparatively lesser. Application of fly ash at 2-4% enhanced dry matter yield of paddy, while at 8% decrease in dry matter yield was reported by Sikka and Kansal (1995). Plant growth and food quality of barley, bronues and lucerne under 0, 25, 50, 100, 200 and 400 t ha\(^{-1}\) of fly ash was observed by Hammermeister \textit{et al.} (1996). They reported significant increase in yield of barley at intermediate rates of fly ash. Barley was grown by Sale \textit{et al.} (1996) on weathered soil mixed with unweathered fly ash and observed an increase in plant height and grain yield under 6.25% and 12.5% fly ash, while at 25% there was no appreciable increase. At Hisar, Gupta \textit{et al.} (1996) conducted a greenhouse experiment to study the interaction of fly ash and phosphorus on yield and P uptake by wheat and observed decrease in grain and straw yield when fly ash was applied beyond 25%. At the same place Grewal \textit{et al.} during the year 2001 reported that fly ash enhanced the grain as well as straw yield in pearl millet and wheat when grown up to 20% fly ash. Uptake of N, P and K in grain and straw of both the crops was also higher under fly ash treated plots as compared to control.


Sugawe \textit{et al.} (1997) at Parbhani (Maharashtra) studied the response of sunflower to the graded levels of fertilizers and fly ash. Five fertility levels namely F\textsubscript{1}-FYM at the rate of 10 t ha\(^{-1}\); F\textsubscript{2}-100% RDF (60:40:30); F\textsubscript{3}-75% RDF; F\textsubscript{4}-50% RDF and F\textsubscript{5}-F\textsubscript{1} + F\textsubscript{2} and five fly ash levels 0, 5, 10, 15 and 20 t ha\(^{-1}\) were considered. Application of FYM at the rate of 10 t ha\(^{-1}\) + 100% RDF recorded better seed yield although it was at par with F\textsubscript{2}. Application of fly ash at the rate of 10 t ha\(^{-1}\) gave the maximum seed yield. Birajdar \textit{et al.} (2000) also at Parbhani conducted an experiment to study the effect of fly ash and FYM on nutrient availability of soil and yield of...
sweet potato. There were three levels of fly ash (0, 5, 10 and 15t ha\(^{-1}\)) and two levels of FYM (10 and 15t ha\(^{-1}\)). The recommended dose, N\(_{60}\)P\(_{60}\)K\(_{120}\) was given after planting. Application of fly ash increased the tuber yield significantly with each increment dose upto 15t ha\(^{-1}\). FYM also increased the tuber yield.

Masilamani and Dharmalingam (1999) in Tamil Nadu, studied the germination behaviour of teak drupes in fly ash added medium. The older drupes germinated and produced more and better quality seedlings than the fresh drupes. The best germination was observed in the fly ash + red earth + FYM mixture. Selvakumari et al. (2000) also in Tamil Nadu, studied the effect of integration of fly ash with fertilizers and organic manure on rice in Alfisols and reported an increase in yield at 20 and 40t ha\(^{-1}\) of fly ash. The treatments receiving N, P and K as fertilizers or fertilizer + compost or fertilizer + *Azospirillum* recorded an increase in yield over the treatments without any manural addition. The highest yield was recorded when fly ash applied at 40t ha\(^{-1}\) in combination with fertilizer, compost and *Azospirillum*.

Gregorczyk (2000) at Szczecin (Poland), also observed its effect and the product of removing SO\(_2\) and NO from waste gases coming from power station, as a source of fertilizer, on yield and composition of spring rape. Fly ash was applied at 0.3 or 0.6kg 9kg\(^{-1}\) capacity ‘Mitscherlich’ pot and N was applied at 0.5, 1.5 or 3.0g pot\(^{-1}\). No significant differences were found in the yield with different treatments. Application of 0.6kg ash pot\(^{-1}\) reduced dry matter yield as compared to control.

Sharma et al. (2001) at Dadri, reported the effect on soil health and yield of maize and rice under field conditions. The grain yield of maize and rice in fly ash treated plots was found to be increased. Tomato plant growth and yield under 1, 2, 3 and 4kg fly ash m\(^{-2}\) applied to soil by broadcast or in rows was studied by Khan and Singh (2001). Plants grown in ash treated plots especially at 3 or 4kg dose, showed luxuriant growth and greener foliage. Growth and yield of three tomato cultivars were increased as compared to control. Naveen et al. (2001) at Anamalai, observed the effect of gypsum and lignite fly ash (LFA) as sources of sulphur on ragi (*Elusives coracerno*) cv. CO-12. The treatments were, control; gypsum at 80kg ha\(^{-1}\); 160kg ha\(^{-1}\); 240kg ha\(^{-1}\), LFA at 2.1t ha\(^{-1}\); 4.2t ha\(^{-1}\) and 6.3t ha\(^{-1}\). Gypsum at 240kg ha\(^{-1}\) gave the highest values for total dry matter production, grain yield and straw yield.
Rautaray et al. (2003) conducted a field experiment to study the direct effect of fly ash, organic wastes and chemical fertilizers on rice and mustard. The effect of fly ash on mean rice equivalent yield of the rice-mustard cropping sequence was highest when it was used in combination with organic wastes and chemical fertilizers.

2.3 Effect of NPK on chickpea (*Cicer arietinum* L.)

Among various essential plant nutrients, N, P and K are considered to be of prime importance as these are absorbed and utilised in larger quantities. Therefore, a balanced dose of these nutrients in presence of specific biofertilizers can give much better results in leguminous crops. The requirement of these nutrients for different crops has been worked out and reported from time to time. In fact, there is sufficient literature available regarding this aspect for various leguminous crops (Subrahmanyam and Varshney, 1974; Paricha et al., 1983; Badole et al., 1991; Kushwaha and Singh, 1992; Singh et al., 1992; Singh et al., 1993; Yahiya and Samiullah, 1994; Patra et al., 1995; Rana et al., 1998; Kumar et al., 2000; Vyas et al., 2001; Bhat et al., 2002; Singh, 2002; Golakiya et al., 2002; Gundalia et al., 2002; Vijaybaskaran and Thirumurgan, 2002).

In the following pages some of the important and relevant trials conducted specially on chickpea in relation to NPK were considered briefly. Because, the present study is not based only on fertilizer doses but it includes mainly the use of thermal power plant wastewater as a source of irrigation and nutrients in addition to the fly ash released from the same source.

Javia et al. (1989) reported that seed yield increased from 2.08 t ha$^{-1}$ to 2.19 t ha$^{-1}$ when 20 kg N ha$^{-1}$ was applied to chickpea. On the other hand yield with 0, 25 or 50 kg P$_2$O$_5$ ha$^{-1}$ was found to be 1.99, 2.14 and 2.28 t ha$^{-1}$ respectively. In the same year, Sharma et al. observed an increase in seed yield when 18 kg N ha$^{-1}$ was applied. Singh et al. also in the year 1989 found that reduction in recommended fertilizer rate i.e. 18 kg N ha$^{-1}$ and 40 kg P$_2$O$_5$ ha$^{-1}$ had little effect on yield, whereas yield of rape seed and especially wheat were decreased by reducing the fertilizer rates to 25-66% of the recommended rates of 120 kg N + 60 kg P$_2$O$_5$ ha$^{-1}$ for wheat and 80 kg N + 60 kg P$_2$O$_5$ ha$^{-1}$ for rape.

Thakur and Jadhav (1990) in Maharashtra applied N + P$_2$O$_5$ @ 12.5 + 25,
25+50 or 37.5+75 kg ha\(^{-1}\) and obtained the seed yields of 3.23, 3.52 and 3.58 t ha\(^{-1}\) respectively when compared with 3.12 t ha\(^{-1}\) without the application of nitrogen and phosphorus.

At Aligarh, Yahiya and Samiullah (1995) reported that 40 kg P\(_2\)O\(_5\) ha\(^{-1}\) proved to be the most effective dose for nodulation, N\(_2\) fixation, leaf area, shoot dry weight, nodule dry weight and acetylene reduction. During their observations P content of shoot and root, soluble sugar content of nodules and N uptake of shoot were also increased. At the same place, Inam \textit{et al.} (1996) while working on potassium noted 50 kg ha\(^{-1}\) as the best dose for pods plant\(^{-1}\), seed yield and the biological yield of this crop. In another field trial Yahiya \textit{et al.} (1996) further observed the increase in leaf area index, shoot dry weight, nodule number, nodule dry weight, acetylene reduction activity of nodules, shoot nitrogen accumulation, shoot and root potassium content and soluble sugar content of nodules with K supply. Application of 40 kg ha\(^{-1}\) proved optimum in most of the parameters studied.

Khurana and Dudeja (1996) found that high nodulating (HN) and low nodulating (LN) selections of chickpea cv. ICC-4948 and ICC-5003 remained high and low nodulating respectively at two nitrogen levels (0 and 100 kg N ha\(^{-1}\)). ICC-4948 recorded 5.4–25% higher seed yield with an increase in nitrogen level from normal to 100 kg ha\(^{-1}\). However, in ICC-5003 decrease in yield was observed with increasing the nitrogen level.

Yadav and Srivastava (1997) at Morena (MP) in a field trial of chickpea cv. JG-315 gave 0, 20, 40 or 60 kg P\(_2\)O\(_5\) ha\(^{-1}\) with and without seed inoculation with phosphate solubilizing bacteria (PSB). Highest yield was given by 60 kg P\(_2\)O\(_5\) ha\(^{-1}\)+PSP followed by 60 kg P\(_2\)O\(_5\) alone. Similarly, Gupta \textit{et al.} (1998) while working in Madhya Pradesh in a field experiment, inoculated the seeds of chickpea cv. JG-74 with \textit{Rhizobium} and \textit{Bacillus} or uninoculated giving 0–40 kg P\(_2\)O\(_5\) ha\(^{-1}\) as single super phosphate (SSP) or 40 kg P\(_2\)O\(_5\) as rock phosphate. Seed yield was more with inoculation. Application of 40 kg P\(_2\)O\(_5\) as SSP produced the highest mean seed yield of 1.06 t ha\(^{-1}\). Inoculation and phosphorus application increased the N and P uptake and seed crude protein content.

Also in Madhya Pradesh Patel (1998) performed a field experiment under
irrigated conditions. The crop was given 0–60 kg P$_2$O$_5$ ha$^{-1}$ and various combinations of 20 kg N, seed inoculation with *Rhizobium* and foliar application of 2% diammonium phosphate (DAP). Mean seed yield was highest with 60 kg P$_2$O$_5$. The combined application of 20 kg N + seed inoculation with *Rhizobium* + foliar application of 2% DAP gave the highest seed yield. Sonboir and Sarawagi (1998) at Raipur gave different combinations of 0–60 kg P$_2$O$_5$ ha$^{-1}$, phosphate solubilizing bacteria (PSB), *Rhizobium* and trace elements. Highest seed yield was found under the treatment 60 kg P$_2$O$_5$ + PSB + *Rhizobium* + seed application of Mo and Fe. This treatment also gave the maximum nodulation. Again Sarawagi *et al.* (1999) reported that N and P uptake increased with increase in levels of phosphorus and was further increased with the application of phosphate solubilizing bacteria (PSB) alone or in combination with *Rhizobium* culture (RC). Seed yield was increased by the use of PSB and RC along with phosphate fertilizers. Guhey *et al.* (2000) also from Raipur reported an increase in seed protein content with increase in phosphorus levels i.e. 20, 40, 60 or 80 kg ha$^{-1}$. Sugar content increased up to pod filling, then declined.

Joseph and Sawarkar (1999) at Jabalpur utilized the low grade rock phosphate (RP at 80 and 160 kg ha$^{-1}$) in meeting the phosphorus requirement by amending with farmyard manure (FYM, at 5 t ha$^{-1}$), pyrites (at 40 kg ha$^{-1}$) and phosphate solubilizing bacteria (PSB) and found an increase in biomass with increasing level of phosphorus. Application of RP amended with FYM resulted in the highest concentration of ‘P’ and ‘Zn’ in biomass of chickpea. Singh *et al.* (1999) at Bilaspur (MP) observed that application of poultry manure and *S. rostrata* produced higher yield of rice and chickpea at 80 (N), 50 (P$_2$O$_5$), 30 (K$_2$O) kg ha$^{-1}$ level of chemical fertilizer. Jain *et al.* (1999) also in MP reported that when seeds of chickpea were inoculated with *Rhizobium* and/or phosphorus solubilizing bacteria (PSB) and given 30, 45 or 60 kg P$_2$O$_5$ ha$^{-1}$ then nodulation, pods plant$^{-1}$, seed and stover yield were increased with phosphorus application. Combined inoculation of *Rhizobium* and PSB + 60 kg P$_2$O$_5$ produced the highest mean seed yield and the maximum net returns.

Braga and Vieira (1998) at Coimbra (Brazil) in a field experiment inoculated seeds of chickpea with *Bradyrhizobium* or not inoculated and given 0 or 30 kg N ha$^{-1}$, 0 or 40 g Mo ha$^{-1}$ and 0 or 40 kg micronutrients ha$^{-1}$ i.e. Zn, B, Cu, Fe, Mn and Mo.
Inoculation gave the maximum seed yield, followed by N fertilizer. Carrasco (1998) in Spain inoculated the seeds of chickpea with 2 strains of *Rhizobium* or not inoculated and applied the recommended nitrogen rate or no nitrogen. Seeds yields were highest with seed inoculation.

Takankhar et al. (1998) in Maharashtra, inoculated the seed of chickpea with *Rhizobium* or not inoculated, and gave 0–75kg P$_2$O$_5$ and 25 or 50kg N ha$^{-1}$. Seed inoculation and the application of nitrogen and phosphorus significantly increased P uptake. The application of 75kg P$_2$O$_5$ produced the highest seed yield.

Bhuiyan et al. (1999) at Rangpur (Bangladesh) reported that seed yield, nodulation, nodule weight shoot weight and stover yield of chickpea were highest in treatments with *Rhizobium* + P + K + Mo + B. The seed yield in this treatment was increased upto 204% over the unfertilized, uninoculated control. During the same year Das et al. in Himachal Pradesh found that P @ 80kg ha$^{-1}$ produced the highest N, P and K contents in the grain and straw, total N, P and K uptake, and grain and straw yield.

Hadi and Sheikh (1999) at ElRwakeeb (Sudan) studied the effect of seed inoculation with *Rhizobium* and nitrogen fertilizer application @ 50kg ha$^{-1}$. They found that *Rhizobium* inoculation or nitrogen fertilizer application significantly increased the total nodule number plant$^{-1}$, 100 seed weight, yield and protein content of seeds.

Alloush et al. (2000) at Beaver (USA) observed that when chickpea was given phosphorus in various combinations, an increase in shoot dry matter, and accumulation of P, S, Mg, Ca and K was observed. Similarly during their study on phosphorus. Mukherjee and Rai (2000) at New Delhi, observed that 0 and 60kg ha$^{-1}$ exhibited perceptible influence on yield of the crops. Biofertilizer and phosphorus interaction showed significant influence on growth and P uptake by wheat and chickpea compared with either of the components applied separately.

Krishna et al. (2001) at Kanpur studied the effect of 3 levels (0, 15 and 30kg ha$^{-1}$) of nitrogen on nodulation, yield and N uptake. Nitrogen at 30kg ha$^{-1}$ produced the highest nodule number, seed yield plant$^{-1}$, test weight and N uptake. At Cairo (Egypt) Shetaia and Soheir (2001) while working on yield and its components in
Review of Literature

response to phosphorus fertilization reported that $P_2O_5$ at 40kg feddon$^{-1}$ significantly increased the pods plant$^{-1}$, pod weight plant$^{-1}$, seed yield plant$^{-1}$ and seed and straw yield feddon$^{-1}$. Sawires (2001) at Giza (Egypt) found that 23.25kg $P_2O_5$ feddon$^{-1}$ recorded the highest number of pods plant$^{-1}$, pod weight plant$^{-1}$ and seed and straw yield.

Kurdali et al. (2002) at Damascus (Syria) evaluated the impact of three rates of potassium (0, 75 and 150kg K$_2$O ha$^{-1}$) on nodulation, dry matter production and nitrogen fixation by faba-bean and chickpea in a pot experiment. The higher level of potassium increased both dry matter production and total N$_2$ fixed in faba bean but did not have any effect on chickpea.

Kumar et al. (2003) at Hisar reported the effect of P and K fertilizers, alone and in combination on chickpea under moisture deficit condition. Phosphorus and potassium were applied through single super phosphate and muriate of potash at the rate of 50kg ha$^{-1}$ each after germination. Treatment with phosphorus and potassium increased the dry weight of leaves and stem. The relative water content of leaves also increased significantly with fertilizer application. Application of fertilizers proved beneficial in terms of grain yield. Tomar et al. (2002) at Junagadh noted the effect of graded doses of potassium (0, 25, 50, 75 and 100kg ha$^{-1}$) on two varieties of chickpea. Its application increased the grain and straw yield, 100 seed weight, protein content and concentration of K and N in grain and straw. 50kg K$_2$O ha$^{-1}$ was found optimum.

Conclusion

It may be concluded that wastewater has been tested under various conditions with different crops. Response to wastewater varied from region to region, crop to crop and source to source. In most of the cases lower concentration proved beneficial as it contains some essential elements while the higher was deleterious as it becomes toxic. Fly ash is another potential source of many macro- and micro-nutrients to plants although it contain some toxic metals also. Its application with various organic amendments and biofertilizer treatments can improve soil quality and lead to higher fertility. Various categories of plants can be grown on fly ash, but members of leguminosae seems to be advantageous. Plants, such as chickpea, which has a $Rhizobium$ symbiont for nitrogen input and that exerts a metal detoxification
mechanism such as PC synthesis, demonstrate the possibility to grow such crops in fly ash contaminated soil and the water incidently which is generated in large quantities from the same thermal power plant may also be used as a source of irrigation.