CHAPTER II. REVIEW OF LITERATURE

As already stated in Chapter-I agriculture is the largest user of fresh water globally and is one of the major cause of the degradation of the surface and ground water. Agriculture has become the largest non point source of pollution except for the water lost through evapotranspiration, agricultural water is recycled back to the surface and ground water. The expansion of irrigation and steadily increasing use of fertilizers and pesticides to sustain higher yields have had an adverse impact on both the production and environment. In order to conserve the precious resource of fresh water, it has become necessary to control the pollution created by agriculture and allied operations.

The precarious situation with regard to the supply and demand of water globally, and more particularly in the populous developing countries, requires that measures for the conservation and sustainable use of water be strengthened. Agriculture today is faced with the challenge of having to produce more from less water. This along with the environmental destruction and socio economic cost brought about by unsustainable use of water in the past, requires that more grain per drop of water, environmental conservation and social responsibility for the sustainable development becomes the mantra of this century.

Agriculture does not always need water of very high quality therefore, slightly brackish water and marginally treated municipal wastewater can be used for irrigating crops and this actually is a good option to improve the productivity and in many studies world wide, the use of wastewater as a source of irrigation and nutrients has actually been introduced as viable alternative for sustainable use of water and environmentally sound wastewater disposal practice compared to its direct disposal to land and surface water bodies. Keeping in view the agronomic and environmental aspects this review was under taken to:

- Present the overview of the effect of wastewater on *Cicer arietinum* L. used as test crop during our study, some other leguminous crops and non leguminous crops.
However, the plant nutrition only through wastewater can not meet the high nutrient requirement of the crop and thus supplemental fertilizer needs to be added so as to get the optimum yield. Therefore, the present review was also under taken to:

- Present the role played by fertilizers mainly nitrogen, phosphorus and potassium in increasing the yield of chickpea.

### 2.1 Effect of wastewater on *Cicer arietinum* L.

Srivastava and Sahai (1987) at ecological research laboratory (Gorakhpur) conducted the study to evaluate the effect of distillery effluent applied in concentrations 1, 2.5, 5, 10, 25, 50, 75, 100% and control on germination, growth, reproductive capacity and yield. They reported a decrease in the percentage and speed of germination of seeds with an increase in the effluent concentration and at 100% concentration the seeds could not germinate. Shoot length was maximum at 5% of the effluent concentration while maximum root length was observed at 2.5%. A gradual increase in the root and shoot length, leaf area, biomass, net primary productivity, pigment content, reproductive capacity, seed output, seed weight and seed protein content was observed from control to 5% concentration and thereafter, a decrease was observed. Thus, they finally concluded that effluent concentration up to 5% concentration was beneficial and therefore could be used as a liquid fertilizer. They were of the opinion that the excessive concentration of soluble salts and high BOD in the higher effluent concentration could be responsible for this decrease.

Gagan *et al.* (1989) conducted this experiment to find out the potential of recycling of sewage sludge irradiated with gamma rays to utilize it as a fertilizer, using chickpea as test crop. The study was carried out in pot cultures and the effect of gamma irradiated and un-irradiated sewage sludge was compared to plants grown without sludge. They reported significant reduction in the root length, fresh and dry weights of plants grown in soil amended with un-irradiated sludge. This inhibition in growth however, was nullified when the plants were grown in soil supplemented with gamma irradiated sludge suggesting that the gamma irradiation induced inactivation of toxic substances in sewage sludge. They further reported that the protein content of the plants grown in soil supplemented with gamma irradiated sludge was significantly increased compared to those grown with un-irradiated or no sludge after 45 days.
However, no significant effect of gamma irradiated sludge on shoot length, total soluble sugars, starch content and yield of chickpea plants was observed. They finally suggested recycling of gamma irradiated sludge for agricultural purpose showing the possibility of its safe and beneficial use.

Shukla and Pande (1991) observed the negative impact of wastewater from acid manufacturing industry on seed germination of three crop plants. At 25% effluent concentration, seed germination and seedling length of maize, mungbean and chickpea was 86, 32 and 55% while at 50% it was 52, 12 and 15% respectively. Germination was 100% in distilled water. Agarwal and Gupta (1992) investigated the effect of nitrogenous fertilizer factory effluent on seedling growth and biochemical properties of chickpea and mustard and reported the deleterious effect of the effluent. They observed that the inhibitory effect was more pronounced on radicle than hypocotyl. They further reported a significant decrease in the pigment concentration of the seedlings due to effluent.

Sharma and Habib (1995) at Bareilly, studied the effect of rubber factory effluent on different cultivars of five rabi crops viz. wheat (Triticum aestivum) var. RR-21 and UP-262, gram (Cicer arietinum) var. PG-114 and C-235, pea (Pisum sativum) var. auricle and P-5, mustard (Brassica campestris) var. varuna and T-59 and barley (Hordeum vulgare) var. Jyoti and BG-39. They observed that concentration of Mg in the straw and dried hay of all the cultivars irrigated with effluent mixed wastewater decreased. Also the percentage of Ca, K, PO₄, total nitrogen, crude protein and ether extract was significantly lower in seeds of the effluent treated cultivar C-235 of gram. During the same year, Shivhare and Pandey (1995) at Raipur (India) after observing the effect of copper ore effluent on the percentage germination and seedling height of gram, vigna, wheat, maize and paddy rice reported that the response of these parameters to effluent was concentration dependent. They observed that 50% effluent was favourable while 100% showed the deleterious effect. In their opinion this kind of response of effluent was due to the presence of xanthate which was present up to the level of 143 mg/l.

Shukla and Moitra (1995) at Shillong soaked the seeds of gram (Cicer arietinum), black gram (Vigna mungo), maize (Zea mays) and rice (Oryza sativa) in 0,
25, 50, 75 and 100% concentration of steel plant effluent. Seed germination and seedling growth of all the crops decreased with an increase in the effluent concentration while lowest tolerance limit to effluent was observed in case of maize. While taking ten different crops Singh and Bahadur (1995) at Pantnagar conducted a petriplate experiment to study the effect of distillery effluent on number of crops including rice, wheat, blackgram, greengram, pigeonpea, lentil, mustard, soybean, maize and chickpea. No germination was reported in 100% effluent in crops tested while maize, rice, mustard, blackgram, pigeonpea, soybean, and chickpea germinated under 20% effluent and seeds of greengram germinated normally up to 50% of the effluent concentration. In case of wheat, seeds were more sensitive to 50% while the germination of rice and lentil was adversely affected at 50% level. Aziz et al. (1996a) at Aligarh studied the long term effect of effluents from petroleum refinery of Mathura under field conditions on six crops including chickpea and agricultural soils. They observed that wastewater irrigation increased the seed yield of all the crops viz. wheat, triticale, chickpea, lentil and pigeon pea except that of summer moong.

Ghosh et al. (1999) at Patna conducted this experiment to study the effect of various concentrations of distillery effluent on germination of pea (Pisum sativum), gram (Cicer arietinum) and black gram (Vigna mungo). In gram and pea, the percentage germination increased up to 75% of the effluent concentration and up to 50% in blackgram. Plumule and radicle growth generally increased up to 50% or 75% effluent and then decreased. In their study, the root shoot ratio was also decreased with increasing level of effluent concentration.

Kumawat et al. (2001) at Ujjain while taking wheat and chickpea as test plant in their experiment using 0, 25, 50, 75 and 100% base and caustic yellow dye effluent, reported that higher effluent concentration decreased the germination, root and shoot length and dry matter production of the two crops tested. On the other hand, marginal increase at lower concentration of 25% was observed. They suggested that proper crop cultivar selection should be considered before effluent use.

El-Hadrami et al. (2004) during their study revealed that the traditional and industrial olive mill wastewater (OMW) samples were mildly acidic (pH = 4.10 - 4.50) and with high conductivity of 18 to 56 ms cm⁻¹. The chemical oxygen demand
(COD) ranged from about 250 to 600 gm L\(^{-1}\) while biological demand of oxygen was about 3.05 to 3.39 gm L\(^{-1}\). The two OMW samples also showed significant difference in contents of many other chemical elements such as sodium, chloride, phosphorus and soluble and bound phenolic compounds. The experiments were carried out in petridishes using seeds of durum wheat, maize and tomato and in order to evaluate the OMW effects and green house experiments were also performed using wheat, maize and chickpea as test crops. After pre-treatment within the petridishes, plantlets were transferred into the green house in plastic bags containing 2.5 kg of soil mixed with sand and peat (2:1, v/v). Two plantlets per pot and three pots per treatment were used. Results revealed significant differences in germination ability among different crops when treated with OMW or aqueous phenolic extracts of OMW solutions. Maize showed a high germination index up to 25% of OMW whereas chickpea was also able to germinate in the range of 25 to 50% of OMW but in contrast the germination in wheat and tomato was noticed up to 15 and 5% of OMW respectively. Significant qualitative and quantitative differences of some stress indicators such as phenolic compounds, peroxidases, chlorophyll contents were also detected. The reduction of chlorophyll contents was reported to be accompanied by 3 to 5 times stimulation of peroxidase activities. Phenolic compounds accumulation up to 1.25 to 7 times was also observed for OMW treated plants compared to controls.

The effect of untreated and treated olive mill wastewater (OMW) on seed germination, plant growth and soil fertility were studied by Mekki et al. (2006). Tomato (*Lycopersicon esculentum*), Chickpea (*Cicer arietinum*), bean (*Vicia faba*), wheat (*Triticum durum*) and barley (*Hordeum vulgare*) were tested for germination index and growth in soil irrigated with OMW. The results showed beneficial effects of using treated OMW and the plants showed an improvement in seed biomass, spike number, plant growth and a similar or even better dry matter productivity than plants irrigated with water. Inhibition in the seed germination, leaf necrosis and low productivity was reported with untreated olive mill wastewater.

Rija *et al.* (2005) at Karachi University in Pakistan conducted this study to find out the changes in biochemical properties of *Vigna radiata*, *Cicer arietinum* and *Lens culinaris* after irrigation with sewage wastewater at alternate day's up to a period
of four weeks. All the biochemical parameters i.e. chlorophyll, protein and carbohydrate content showed a considerable increase in treated samples than the control. Nawaz et al. (2006) also in Pakistan at Rawalpindi conducted a petriplate study to evaluate the effect of three different industrial effluents on seed germination and early growth. Water samples were collected and two different varieties of *Cicer arietinum* (P-9 and P-2000) were selected to grow in these effluents. Physicochemical parameters (pH, temperature, dissolved oxygen, conductivity, turbidity, total dissolved solids, total suspended solids etc.) of these samples were analyzed. Both varieties were grown in different dilutions of effluents. With the increase of the effluent concentration, growth was found to be more affected in Koh-e-Noor mill effluent while less effect was observed in Marble and Attock refinery limited (ARL) effluents. Percentage germination of variety P-91 in Koh-e-Noor mill effluent was 100% in all concentrations except in 80% effluent where germination was decreased to 93.75%. Minimum germination was recorded in ARL effluent at 80% level. They further reported decrease in the root length with the increase in the effluent concentration of Koh-e-Noor mill. However, an increase in the root length at 10% effluent was recorded which decreased to 62.32% at 100% effluent in var. P-91 while an increase in the root length was recorded in all concentration of marble industry effluent with the maximum increase recorded by 20% effluent and the minimum by 40%.

Garg and Kaushik (2006) at Hissar conducted a pot experiment to study the effect of textile mill effluent (treated and untreated) with 0, 6.25, 12.5, 25, 50, 75, 100% concentrations on germination, delay index, physiological growth parameters and plant pigments of two cultivars of chickpea. At a low concentration of 6.25%, the textile effluent did not show any inhibitory effect on seed germination including other parameters (delay index, root and shoot length, dry weight, chlorophyll and carotenoid content) also followed the same trend, while at 100% concentration seeds germinated but could not survive at later stage. Furthermore, in treated effluents the two varieties had a lower rate of germination than the control. The germination in Channa No. 3 was 90% in ≤ 75% of treated effluent and this variety showed better germination than Channa No. 1. They further reported the adverse effect of the
effluents on dry mass accumulation and at ≥ 25% effluent, decrease in shoot dry weight was observed. They were of the opinion that probably the high salt content of the effluent was responsible for the reduction in dry biomass at 25, 50, 75 and 100% effluent concentrations while the better growth at lower concentration (6.25%) was due to the presence of nitrogen and some other essential mineral nutrients.

Tannery effluents besides containing valuable nutrients also contain salts, heavy metals, pathogens and dyeing agents and because of lack of proper waste disposal, it is one of the most serious concerns to the environment. To determine the effect of tannery wastewater on some germination properties of wheat, maize, rice, chickpea, bean, soybean, sunflower and soybean seeds a study was conducted by Tayyar et al. (2008) in Turkey. A completely randomized block design experiment was carried out in petriplates. Four concentrations of effluent (1:0, 1:10, 1:40 and 1:80) including tap water as control were analyzed for some physical and chemical properties. Effluent although was rich in some plant nutrients, but undiluted tannery effluent (1:0) significantly decreased and inhibited the seed germination compared to remaining concentrations.

2.2 Effect of wastewater on leguminous crops

Sahai et al. (1985) at Gorakhpur conducted laboratory experiments to study the impact of various concentrations of distillery effluent on germination and growth of Phaseolus radiatus L. The effluent was reported to be highly acidic containing high amounts of calcium, chlorides, bicarbonates, nitrogen and total dissolved solids (TDS). They further reported decrease in germination percentage and speed of germination index with increasing effluent concentration. However, with 5% effluent concentration, considerable increase in respective lengths of root and shoot, plant biomass, net primary productivity, seed output and chlorophyll content was observed. They were of the opinion that the reuse of distillery effluent for irrigation would not only solve disposal problem but may also serve as an additional source of liquid fertilizer. While working at the same place, Mukherjee and Sahai (1988) further observed that the 5% of the effluent concentration provided the optimum condition for germination, seed output and dry weight of Cajanus cajan (Pigeon pea). Seedling establishment was 100% at 5% effluent and the maximum shoot length was recorded
at 2.5% concentration. Further studies were conducted by Sahai and Neelam (1987) to study the effect of distillery effluent mixed with fertilizer factory effluent on black gram and made more or less similar observations. Neelam and Sahai (1989) performed another study on *Vigna radiata* (Greengram) using the same effluent and reported marked increase in the respective length of root and shoot, plant biomass and N-uptake when plants were grown with 10% distillery effluent. Total N in root, stem and leaf increased even up to 30% of the effluent concentration. Jabeen and Saxena (1990) also at Gorakhpur observed that a lower concentration at 5% of distillery effluent and 2.5% of fertilizer factory effluent favoured the growth leading to increased dry matter, pigment and protein content in pea and suggested that after proper dilutions both wastewaters could be used as a source of nutrients.

In an experiment conducted in pots at Bangalore, Pathmanabhan *et al.* (1987) studied the effect of paper mill effluent on various varieties of groundnut (*Arachis hypogaea*) and reported that the pod number per plant, seed weight per plant and 100 seed weight showed a reduction due to effluent irrigation and also revealed varietal differences. The dry weight of the leaf and stem at harvest decreased significantly due to irrigation in most of the varieties. Pathmanabhan and Udaiyakumar (1988) further reported that the paper mill effluent irrigation decreased the activities of carboxylating enzyme and nitrate reductase in groundnut (*Arachis hypogaea*) and finger millet (*Eleusine coracana*) seedlings grown in sand culture. The PEP carboxylase activity in finger millet suffered more reduction than that of RuBP carboxylase in groundnut. While large scale cultivation of sugarcane (*Saccharum officinarum*), paddy (*Oryza sativa*), wheat (*Triticum aestivum*), onion (*Allium cepa*) and ground nut (*Arachis hypogaea*) using treated effluent from Pudumjee Pulp and Paper Mills Ltd., Pune, confirmed that the lignin, polysaccharides and residual nutrients present in the effluent were helpful and increased the yield (Kulkarnii, 1988).

Deivasigamani *et al.* (1989a) at Annamalainagar, conducted studies on the effect of raw textile wastewater on blackgram (*Vigna mungo*). The raw wastewater inhibited all morphological growth parameters like shoot length, root length, number of nodules, number of leaves, leaf area and yield of blackgram and in yet another study (1989b) they reported that the seed hardening with CaCl₂ checked the adverse
effect of wastewater irrigation on growth and yield. Similarly seed hardening with CaCl₂ has also been reported by Subramanian et al. (1990a) at the same place. They conducted the experiment to study the effect of pre-sowing hardening treatment under distillery effluent on growth and yield of blackgram (Vigna mungo). Growth parameters like shoot length, root length, number of root nodules, number of leaves, total leaf area and yield were reduced under effluent irrigation. For increasing the yield, they gave seed hardening treatment with CaCl₂ which amended the adverse effect of wastewater by enhancing growth and yield to a certain extent. They further conducted another experiment (1990b) on the effect of same distillery effluent on seed germination and seedling growth of green gram (Vigna radiata). The studies were conducted in petridishes under different concentrations of effluent (10, 25, 50, 75, 100%). Lower concentrations of effluent showed favourable effect on seedling growth whereas higher concentrations inhibited the viability and percentage of germination. The shoot and root length was found to be decreased with increase in effluent concentration. However, Somashekhar et al. (1992) reported that the concentration of distillery effluent had a direct bearing on the rate and percentage of germination in cowpea and fenugreek while biomass showed a decreasing tendency with the increasing concentration. Kannabiran and Pragasan (1993) while working on similar effluent at Pondicherry reported that the seeds of blackgram failed to germinate in undiluted effluent. Vijaykumari and Kumudha (1990) at Erode, also studied the effect of distillery effluent on seed germination and early seedling growth in blackgram (Vigna mungo) and greengram (Vigna radiata). They reported that the germination and seedling growth retarded with increase in effluent concentration. The effluent concentration at 2.5 was reported to be beneficial for overall growth of the plants and finally recommended the use of effluent after proper dilution.

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. Sharma et al. (1990) performed 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* (French bean) 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.

Trivedi and Kripekar (1991) at Karad while investigating the effect of dairy wastewater on growth and mineral composition of soybean and green gram observed increase in the ash, Ca, N and P content of both the crops. In soybean, P content increased in 10, 25 and 50% effluent but decreased in 100% effluent.

Aziz et al. (1993a) at Aligarh carried out pot experiments to study the effect of treated refinery wastewater and groundwater on NR activity of *Vigna radiata* and found a difference in response to two waters and the effluents stimulated NR activity at all the samplings when compared to ground water. A linear increase in the NR activity was recorded from 15 to 25 DAS and thereafter it decreased. Aziz et al. (1993b) again tested the performance of lentil with N<sub>15</sub> P<sub>30</sub> K<sub>40</sub> and no fertilizer under different irrigants. Treated effluents proved better compared to ground water and fertilizer application further enhanced the growth. Inam et al. (1993) also compared the effect of refinery effluent and ground water on triticale and wheat. No significant difference in the percentage of seedling emergence under both waters was observed. Siddiqui et al. (1994) while using the same water studied the response of green gram. An increase in the leaf number, dry weight, seed number and pod number was reported under wastewater irrigation. Effluents together with fertilizer were more effective as compared to ground water for vegetative growth only, however it decreased the seed yield. Javid et al. (2006) at the same place but using different source of wastewater (sewage wastewater and thermal power plant effluent) conducted a pot experiment to evaluate the physiomorphology and yield of black gram (*Vigna mungo*) var. PU-19. Wastewater application promoted the growth, NR activity, total chlorophyll content, leaf nitrogen content and seed yield per plant.
compared to ground water irrigated plants. Tabassum et al. (2007) also at Aligarh performed an experiment using city wastewater to study its impact on the yield of *Lens culinaris* cv. DLP-15 with two concentrations of wastewater i.e. 50%WW and 100% WW with different doses of phosphorus (P₀, P₁₀, P₂₀ and P₄₀) and uniform basal application of 20 kg N and 30 kg K ha⁻¹ respectively. Significant increase in the plant fresh and dry mass, nodule number, seed yield and biomass was observed in plants irrigated with wastewater when compared to ground water.

Earlier also at Aligarh but in another 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 (1984a) 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 (1984b). In yet another study during the year 1985a, they collected textile factory effluent and applied it on kidney bean and 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) further observed the impact of electroplating factory effluent on 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 up to 0.2% effluent. The optimum growth of hyacinth bean was observed with 0.1% effluent. They were of the opinion that only diluted effluents proved favourable for plant growth.

Ramasubramanian et al. (1993) at Sivakasi soaked the seeds of blackgram (*Vigna mungo*) cv. LBG12 for 2 hours in diluted effluent (10-40%) from match and
dye industries and then germinated them in sand culture. They observed decrease in the germination and seedling growth with increase in effluent concentration. They also reported that the decrease in plant fresh and dry mass paralleled the decrease of the leaf pigments (chlorophyll a, b and carotenoids) which they attributed to the degradation of photosynthetic pigments by increased peroxidase activity.

Goyal et al. (1995) at Hissar reported that the application of distillery wastewater up to 160 m$^3$/ha to moong beans (*Vigna radiata*) grown in pots increased the dry matter and N and P uptake but the dry matter decreased markedly with 640 m$^3$/ha. The E.C of the soil was increased about three folds by the application of distillery wastewater equivalent to 320 m$^3$/ha. 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. Similarly, Prasanna-Kumar et al. (1997) at Bhavnagar in their experiment moistened the seeds of greengram (*Vigna radiata*) and blackgram (*Vigna mungo*) with different concentrations of dairy effluent (10, 25, 50, 75, 100%) and found a gradual decrease in the percentage of seed germination, seedling growth and pigment contents with increase in the effluent concentration. However, under 25% level, maximum values for the above mentioned parameters were obtained. They finally concluded that the dairy effluent after dilution to 25% concentration could be safely used for irrigation.

Goswami and Naik (1992) while investigating the effect of fertilizer factory effluent on *Cyamopsis tetragonoloba* Taub (Cluster bean) reported increase in the chlorophyll content under 10% of the effluent but higher concentration had an adverse affect while Subramani et al. (1998) also investigated the impact of similar effluent on cowpea (*Vigna unguiculata* L.Walp) and reported beneficial effect on the overall growth at 10% of the effluent concentration. Earlier Subramani et al. (1995) while carrying out his experiments in petriplates reported decrease in the germination, growth, yield and productivity of green gram with increasing concentration of the effluent. 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 was 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 and it proved tolerant while variety VRI-4 was susceptible. Similarly, Manoharan and Lakshamanan earlier in 1987 reported improved seed germination and early growth of black gram under tannery effluent. They were of the opinion that this increase was probably due to the presence of trace elements and nutrients in the tannery effluent. Balashouri and Prameeladevi (1994) tested similar effluent on green gram, pigeon pea, and sorghum and reported 10% of the effluent as optimum for seed germination, seedling growth, chlorophyll content and biomass production for legumes however, for sorghum optimum concentration was 5%.

Singh and Singh (1997) studied the effect of terpentine factory effluent and Zn on germination, seedling height, fresh and dry mass and chlorophyll content of Cajanus cajan (Pigeon pea). Results revealed deleterious effect of higher concentration while the lower concentration proved to be beneficial.

Ramana et al. (2002) investigated the relative efficacy of three distillery effluents i.e. raw spent wash (RSW), biomethanated spent wash (BSW) and lagoon sludge (LS) with recommended fertilizer dose and farmyard manure and reported an increase in the total chlorophyll content, crop growth rate, total dry matter, nutrient uptake and seed yield in groundnut under the three effluents however, nodulation was inhibited and resulted in decreased nitrogen fixation. Among the effluents BSW produced highest seed yield followed by RSW and LS.

Al-Freedan (2006) in the kingdom of Saudi Arabia conducted an experiment to study the effect of treated municipal effluents and Rhizobia strains on growth and nodulation of faba bean (Vicia faba). Better growth of plants was reported with no symptoms of nutrient deficiency or signs of toxicity under different levels of wastewater. It significantly increased the shoot and root length and nodule development (fresh and dry mass). $N_2$ fixation activity and nitrogen content of plant tissues were also significantly affected by both effluent and Rhizobia treatments and
maximum improvement in growth was reported under 100% effluent application and hence was found to be comparatively more effective than the well water.

Kannan and Upreti (2008) at industrial toxicological research centre Lucknow, studied the influence of distillery effluent on growth of mung bean (*Vigna radiata*). The seeds were pre-soaked for 6h and 30h respectively in different concentrations (5-20%) of each effluent and germination, growth parameters and seedling membrane enzymes and constituents were investigated. Results revealed that the leaching of carbohydrates and proteins (solute efflux) were higher in case of untreated effluent and were also dependent on the pre-soaking time while other germination characters including percentage of germination, speed of germination index, vigour index and length of root and embryonic axis were concentration dependent and significant reductions were observed in untreated effluents. However, effluent up to 10% concentration reflected low levels of the observed adverse effects.

Chandra *et al.* (2008) carried out this study to investigate the effect of distillery sludge amendments with garden soil on seed germination and growth parameters of *Phaseolus mungo*. With the increase in the sludge concentration, germination percentage and index values were decreased however, the plants grown in soils amended with 10% (w/w) distillery sludge showed better growth of root and shoot length, number of leaves, biomass, photosynthetic pigments, proteins and starch. The N, P, K and Mg accumulation was highest in shoot followed by leaf and it was minimal in roots.

### 2.3 Effect of wastewater on non leguminous crops

Many advantages from the use of sewage waste water on crop plants have been reported. According to USDA, sewage finds its use both as a fertilizer source and soil conditioner. It may supply large portion of nitrogen required for crop growth, increase cation exchange capacity of soil and thereby its capacity to retain nutrients (Epstein *et al.*, 1976). It can provide substantial amount of phosphorus (Sommers, 1977) and can be a good source of micronutrients (Fe, Zn, Mn, Cu) for plants (Chen and Stevenson 1986) and there are numerous reports on the role of sewage application in increasing crop production and yield. Increased crop production from the application of sewage sludge and irrigation water into the soil is mainly attributed to
improved soil fertility, increased water retention capacity and increased aeration and this improvement in the soil physical and chemical properties is mainly due to the organic content in the sewage. Although sewage has great fertilizing value and has increased the yields by increasing the soil fertility and water availability yet it may be harmful for the plants and animals including human beings if it contains toxic levels of heavy metals or excessive soluble salts. Ahmad et al. (1994) reported the adverse effect due to increase in the soluble salts and higher SAR in the soil while others have reported the higher values of Cu ions in the effluent than their respective permissible limits (Qadir et al., 1997).

Earlier, Day et al. (1974) conducted experiments at Tucson, Arizona to study the effect of treated municipal effluent on growth, total fibre, acid soluble nucleotides, total protein and amino acids in hay from wheat (Triticum aestivum L.) and reported that wheat plants grown with wastewater had culms with larger diameter. They further observed that the total protein was equalled by wastewater alone when compared with total proteins obtained under well water added with inorganic fertilizers in equal amounts present in wastewater. Similarly, protein was more in plants grown under wastewater than the well water plus the recommended dose of N, P and K. They further noted that the wheat utilized the N in wastewater more efficiently than in the well water plus N, P and K in quantity equal to that present in wastewater. In their opinion, wastewater was an effective source of irrigation water and plant nutrients for the production of high quality hay from wheat. In another study, Day and Cluff (1985) investigated the use of municipal wastewater for the commercial production of sorghum while working at the same place. Total soluble salts and nitrate nitrogen were higher in pump water than in wastewater-pump water mixture. On the other hand the mixture of two waters had more total N, P than the pump water alone. It was also observed that the salt concentration was lower in mixture than the pump water, therefore, making it more suitable for irrigation. Growth, length, heads per unit area and seed yield was increased when the crop was grown under the two waters. They also concluded that it could be effectively used as a source of irrigation water and nutrients.
Feigin et al. (1984) studied the suitability of sewage effluent for drip irrigation of cotton (Gossypium hirsutum) growing on a deep calcareous soil in Israel. The effluent was compared with fresh water at three application rates, the average of which for three seasons were: low (350 mm yr\(^{-1}\)), medium (440 mm yr\(^{-1}\)) and high (515 mm yr\(^{-1}\)). Fertilizer was also given with fresh water. Increase in concentration of available N and P in soil under effluent and fertilizer amended freshwater treatments was observed. On the contrary, K in the soil was increased to a lesser extent and no significant differences in the level of available N, P and K in the soil or in their uptake by plants was detected between effluent and fertilizer amended freshwater. In high application rate effluent treatment, dry matter yield as well as N, P and K accumulation was higher. Bielorai et al. during the same year and at the same place conducted long term drip irrigation experiments to study the influence of municipal effluent along with fresh water on growth, yield and line quality of drip irrigated cotton (Gossypium hirsutum L.) var. ‘Acala SJ-2’. The N concentration in effluent was about 50 mg/L during the three years of experimentation. Cotton plants irrigated with wastewater effluents were taller and showed better vegetative growth when compared to plants grown with fresh water. They were of the opinion that the effluent could be used effectively as a source of water as well as nutrients and with suitable management high productivity may be achieved.

Stehlik (1986) at Harlickuv Brad 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 after dilution. Again in 1987, experiments in petriplates as well as in pots were conducted to investigate the effect of yeast plant wastewater on white mustard. They found that undiluted wastewater had little or no inhibitory effect on germination, whereas separate fractions of wastewater reduced the germination. Dry and fresh yield of pot grown plants were increased by wastewater.

Singh and Mishra (1987) at Kanpur conducted laboratory experiments to evaluate the impact of 2.5, 5.0, 10, 25 and 50% concentrations of fertilizer factory effluent on some physico-chemical properties of soil and germination, growth,
photosynthetic pigments and dry matter production of corn (*Zea mays* L.) and rice (*Oryza sativa* L.). Lower concentrations (2.5 and 5%) enhanced the growth and development of the two crops tested while comparatively higher concentration of effluent (10%) and more inhibited the seed germination and also caused deleterious effect on the dry matter production, yield and photosynthetic pigments of both the crops. Abasheeva and Revenskii (1992) at Uan-Ude (Russia) conducted a pot experiment to study the impact of seleginsky cellulose and cardboard mill effluents on productivity and chemical composition of oat, rape 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 oat 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.

Samiullah *et al.* (1994) at Aligarh observed enhanced leaf number and dry weight in a field experiment on wheat grown under Mathura refinery treated wastewater. Yield characteristics and final yield ha⁻¹ of the crop were also increased. Aziz *et al.* (1994) again tested the 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 refinery effluent resulted in lower protein and carbohydrate content of the grain. 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 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 content of maize seeds were non-significant whereas oil content and oil yield in mustard increased significantly. Tabassum *et al.* (2007) also at Aligarh while using city wastewater as a source of irrigation for mustard, also reported significant increase in the leaf area, photosynthetic rate, stomatal conductance, leaf nitrogen, phosphorus and potassium content and seed yield and attributed this increase due to the nutrients present in the wastewater. At the same
place Akhtar et al. (2008) conducted pot experiment to study the effect of thermal power plant discharged waste water (TPPW) on growth, yield and quality of mustard (*Brassica juncea* L. cv. Alankar) and linseed (*Linum usitatissimum* L. cv. Neelam) and reported an increase in the growth characteristics, net photosynthetic rate, seed yield, oil content and oil yield of both the two crops irrigated with TPPW. In case of linseed, lower levels of nitrogen and phosphorus with waste water proved beneficial. They were of the opinion that it could be considered as an alternative source of water for irrigation purpose and simultaneously could minimize the problem of its disposal.

Al-Jaloud et al. (1995) at Riyadh (KSA) conducted pot experiments to work out the effect of wastewater on mineral composition of corn and sorghum plants. They reported that the heavy metals like Co and Cd were below the detection limits and the concentration of Ca, N, P, K, Cu, Mn, Mg and Zn in sorghum plants were in deficient range except for Fe and Al. Regression analysis indicated strong interaction between Pb, Ni, Ca and Fe in corn and sorghum plants and finally concluded that the wastewater did not increase concentration of macro as well as micro elements or heavy metals in the plants to toxic levels and therefore, may be used for irrigation purpose. Hussain et al. (1996) also in Saudi Arabia under field conditions investigated the yield and nitrogen use efficiency (NUE) of wheat. Two types of irrigation water with or without nitrogen for grain and biomass production were tested. They concluded that if the crop is irrigated with treated effluent containing nitrogen in range of 20 mg L\(^{-1}\) and above, higher NUE and thus higher seed yield may be obtained under low rates of nitrogen.

Mitra and Gupta (1999) during the course of their investigation compared nutrient and heavy metal status of sewage irrigated soils from vegetable growing area of eastern fringe of the city of Calcutta to tube well irrigated soils of Baruipur, South 24-Paraganas district during the monsoon and winter seasons. They were of the opinion that both types of water were suitable for irrigation, although high pH and salt accumulation was observed in sewage irrigated soil. Increased organic matter, nitrogen and phosphorus were also observed in sewage irrigated soils than the tube well water irrigated soil.
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 and 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.

Yoon et al. (2001) conducted a pilot study at an experimental field at Konkuk University (Korea) to examine the effect of treated sewage irrigation on paddy rice culture and its soil characteristics. Treated sewage irrigation had no adverse effect on growth and yield of rice, instead in 10% (with dilution) and 50% (without dilution) higher yield than control was observed.

Ramana et al. (2002) at Bhopal studied the effect of various concentrations of distillery effluent on the seed germination, speed of germination, peak value and germination value in: tomato, chilli, bottle gourd, cucumber and onion. They reported that the effluent at low concentration had no inhibitory effect on seed germination except in tomato and in onion where the germination was 84% at 10% as against 63% in control. However, at higher concentration complete failure of germination was observed irrespective of the crop. 5% concentration was found to be critical for seed germination of tomato and bottle gourd and 25% for other crops. Based on the tolerance to distillery effluents, crops studied were arranged in the order of cucumber > chilli > onion > bottle gourd > tomato.

Al-Lahham et al. (2003) conducted field experiments to investigate the effect of different treatments of potable and treated wastewater on the quality of tomato fruit (Lycopersicon esculentum L.) in Jordan. Tomato seedlings were furrow irrigated with different mixtures of potable and wastewater (1:0, 1:1, 1:3 and 0:1) and the results obtained after irrigation with treated wastewater showed no effect on the fruit pH instead the size of the fruit was increased up to 2 cm in diameter and weight up to 78.7 g but because of contamination of treated wastewater with total coliforms up to
42.0 CFU/100 ml and bacterial count up to 7.820 CFU/100 ml, it was suggested as an alternative for irrigation of tomatoes to be eaten after cooking but not for those taken as raw. Emongor et al. (2005) conducted studies to test the suitability of treated secondary effluent for irrigation of horticultural crops in Botswana. The most important criteria for evaluating irrigation water quality were: salinity hazards (total amount of dissolved salts in water), sodium hazard (the relative proportion of Na$^+$ to Ca$^{2+}$ and Mg$^{2+}$ ions), pH, alkalinity (total amount of carbonates and bicarbonates in water), heavy metal and microbial contaminants. The main effect of EC and TDS of water on crop productivity was their inability to compete with ions in the soil solution for water. The higher the EC and TDS, the less water was available to plants even though the field may appear to be wet. Earlier, Jimenez- Cisneros (1995) suggested the use of treated effluent as an important nutrient source to poor fertility soil for crop production, however Al Nakshbandi et al. (1997) emphasized on the health risks and potential for transmitting wide variety of diseases and illness due to possibility of the presence of wide spectrum of pathogens such as coliforms bacteria associated with contaminated water. However, irrigation with effluents highly polluted with coliforms, faecal coliforms and other bacteria may increase the contamination of irrigated vegetables, but the contamination could be minimized by irrigation with well managed effluents.

Lubello et al. (2004) conducted an experiment to assess the possibility of reusing reclaimed wastewater for nursery ornamental plants at Pistoia (Italy). An experimental plot comprising of six plant species (two each of conifers, Mediterranean evergreen shrubs and deciduous trees) were irrigated with tertiary effluent and growth and physiological parameters were monitored and compared with the plants of control plot irrigated with fertigated water (nutrient enriched ground water). The result showed no major limitation to use tertiary effluent as an irrigation source and was able to maintain good plant growth with the exception of Arbutus unedo (ever green shrub). They finally concluded that the tertiary effluent could be considered as an important fertilizer source for plants like Juniper, Myrtle and Cypress with positive economic and environmental aspects related to the reduction of synthetic fertilizers.
Kaushik et al. (2005) at Hissar conducted laboratory experiments to study the effect of different concentrations (0-100%) of textile effluent both untreated and treated on seed germination (%), delay index (DI), shoot and root length, plant biomass, chlorophyll content and carotenoid contents of three different cultivars of wheat. The textile effluent had no inhibitory effect on seed germination at 6.25% and similar trend was also followed by other plant parameters studied. However, differences were observed in the tolerance to textile effluent for different cultivars. They therefore concluded that the effect of the textile effluent is cultivar specific and suggested that care should be taken before using textile effluent for irrigation.

Fonseca et al. (2005) conducted the research to verify the potential use of secondary treated sewage effluent (STSE) as a source of water and nitrogen for maize and evaluated the nitrogen and phosphorus concentration in the soil, as well as their concentration and content in plants. No variation in total carbon and P concentration in soil was observed, but total nitrogen was increased. Fertilizer application plus treated effluent irrigation increased the P content in plants but without any effect on dry matter yield.

Chattha et al. (2005) conducted studies in different districts of Potowar region of Pakistan to evaluate the quality of sewage for irrigation purposes and heavy metal content. Sixty percent samples collected from different regions were reported to be fit for irrigation while remaining were marginally fit for irrigation. Sodium absorption ratio ranged in between 0.24 to 4.36 and hence were low in Na. Bazai et al. (2005) in a pot study observed the effect of five different concentrations (control, 25, 50, 75 and 100%) of wastewater collected from three different localities of Quetta city (Pakistan) on the concentration of Ca, Na and K and germination and growth in spinach (Spinacea oleracea L). They reported significant difference in the concentration of the three elements among the water of different localities, treatments and their interactions, while showing significant linear increase in the amount of sodium and potassium with increase in the concentration of wastewater. However, in case of Ca such an increase was reported up to a moderate level of effluents beyond which reduction was observed.
Water reclamation and reuse of wastewater has been recognized in different countries as the suitable alternative for compensating the water shortages along with environmental conservation. Similar study was taken up by Naddafi et al. (2005) while assessing the health effects and feasibility of crop irrigation by using stabilization pond effluent of Southern Havaizeh in two experimental plots, one being irrigated by stabilization pond effluent and the other by Nissan river water. Basic parameters in both the plots such as type of cultivated crops, amount of fertilizer used and amount of soil contamination being similar. The only difference was the type of water applied for irrigation. The results showed high salinity of soil reduced the growth rate of agricultural crops however, the growth rate of agricultural crops were increased by using stabilization pond effluent as irrigation water when compared to Nissan river water.

Alvarez-Bernal et al. (2006) in Mexico studied the effluents of leather processing industry discharged normally to river Turbio without treatment and in the downstream is used to irrigate agricultural land. They reported that the tannery contained valuable nutrients beneficial for plant growth and development besides some contaminants such as salts and Cr that might affect the soil properties and crop production. After 25 years of irrigation of agricultural land with water from river Turbio, the soil characteristics were affected as increased E.C, organic carbon and total N-contents (2 times), total concentration of Cr (4 times), copper (2 times) and Na (six times in the clayey soils) compared to soil irrigated with well and irrigation canal water and thus further irrigation with water from Turbio might increase the sodicity and salinity which might deteriorate the soil and pose threat to the future crop production and though the characteristics of the soil and microbial biomass had not deteriorated after years of application of wastewater but oxidation of NO$_2^-$ was inhibited temporarily, which might also affect the biological activities of the soil.

Kiziloglu et al. (2007) in Turkey conducted field studies to observe the effect of different sources of wastewater on macro and micro nutrient distribution in soil and nutrient contents of cabbage (Brassica oleracia) var. Capitata. Wastewater and preliminary treated wastewater significantly affected soil properties essentially at 0-30
cm soil depth and plant nutrient content after one year. Wastewater increased the yield and N, P, K, Fe, Mn, Zn, Cu, B and Mo content of cabbage plants.

Mohammad-Rusan et al. (2007) conducted this study in Jordan at sites irrigated with wastewater for 10, 5 and 2 years and the site not irrigated. Plant analysis and soil analysis were carried out to evaluate its long term effects and reported an increase in the soil N, P and K content being highest in the top soil (0-20cm) and for longer period of wastewater application. Several researchers have reported the accumulation of N, P and K content in the soil irrigated with wastewater and have attributed it to the original contents of nutrients in the wastewater applied. Burns et al. (1985) also reported that wastewater could provide N, P and K in amounts equal to 4, 10 and 8 times of the fertilizer requirement of the forage crops.

Lonigro et al. (2007) in Italy evaluated the use of tertiary filtered municipal wastewater for irrigation as an alternative to fresh water. The water produced after membrane filtration was studied during two years of research and was used for drip irrigation of three vegetable crops in succession- tomato, fennel and lettuce and compared it with fresh water. Microbiological analysis was also performed on water, soil samples and marketable crops. The results showed no relevant differences in relation to two types of water and unexpectedly the plots irrigated with well water turned out to be more polluted, in terms of bacterial contamination than those irrigated with effluent. The heavy metal content in crops never exceeded the toxic values and the bacterial concentration in the soil or edible part of crops did not increase. They were of the opinion that tertiary filtered wastewater may be considered as viable alternative source of water for crop production.

Rehman et al. (2009) in Pakistan conducted growth room experiments to assess as to whether treated textile effluent could safely be used to irrigate some winter vegetables. A considerable reduction in the seed germination and early growth was reported under the effluent irrigation, however this effect was not pronounced at highest concentration. They further reported that the textile effluent did not affect seed germination of the tested vegetables. Photosynthetic pigments and protein contents were more in the leaves of all vegetable plants irrigated with treated effluents. The heavy metal contents of the treated effluent were comparatively lower.
compared to untreated effluent. Based on the germination and growth, *Raphanus sativus* was ranked as the tolerant followed by *Brassica campestris* and *Brassica napus*.

2.4 Effect of NPK fertilizers without wastewater on *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. Infact, there is sufficient literature available regarding this aspect on 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; Golakiya et al., 2002; Gundalia et al., 2002; Singh, 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. The purpose of this part of review is to give an idea that sufficient work has already been undertaken where the source of irrigation water was not wastewater.

Das and Sen (1981) reported reduction in the uptake of P, S, Na, K, Ca, Mn, Fe and Zn under the deficiency of nitrogen, phosphorus and potassium. Dev et al. (1983) at Hissar studied the relationship between P and Mn in chickpea at two growth stages in pot culture using 0, 7.5, 15 and 30 ppm P and 0, 5, 10 and 15 ppm Mn. The application of P increased the dry matter yield at both stages of growth while Mn improved the yield only at the first stage. Addition of 7.5 ppm P enhanced Mn concentration at first stage while at higher levels marked reduction in Mn content was observed at both the stages. Jessop et al. (1984) at New England, Australia under controlled environmental conditions conducted experiment to examine the growth and nodulation under different soil nitrate levels, 0, 0.75, 0.5, 3.0 and 6.0 mM. They reported that the chickpea are less sensitive to inhibitory effects of NO₃⁻ than Soybeans. High NO₃⁻ appeared to inhibit the production of nodules early in growth.
however, by the second harvest nodulation was stimulated by high NO$_3^-$ levels. Responses in tops and roots dry weight production was positive with increasing NO$_3^-$ levels. But proportionally, these effects were greatest with un-inoculated plants.

Sawhney et al. (1985) at Hissar conducted an experiment to study the effect of applied nitrate on growth and N$_2$-fixation. Application of nitrate either weekly or at the time of nodulation and pod filling, retarded nodule development and exerted a delaying effect on the rate of N$_2$-fixation. However, after some time its effect on nitrogenase became less conspicuous. They also reported increase in the nitrate reductase activity in leaves as well as in nodule. The nitrate treated plants at initial stages also accumulated dry mass at a higher rate than those growing exclusively on atmospheric nitrogen. But the nitrate induced premature senescence of plants towards the final stages of growth and lowered both the seed number as well as weight of the individual seed.

Idris et al. (1989) under field conditions of Faisalabad (Pakistan) studied the phosphorus fertilization for yield and nitrogen fixation. 40, 60, 80 and 100kg P$_2$O$_5$ ha$^{-1}$ in the presence of uniform dressing of nitrogen and potash each applied at 20 and 24 kg ha$^{-1}$ improved the nodulation of the crop increased its grain yield, biomass yield, biomass N and biomass P. Parihar and Tripathi (1989) studied the response of chickpea to irrigation and phosphorus at Kharagpur. Increasing the frequency and amount of irrigation reduced the number and dry weight of nodules which increased to a maximum at 70 days after sowing and then declined. The application of phosphorus promoted nodulation and increased both nodule dry weight and the concentration of N, P and K in grain and stover. Javiya et al. during the same year reported that seed yield was increased from 2.08t ha$^{-1}$ to 2.19t ha$^{-1}$ when 20kg N ha$^{-1}$ was applied to chickpea. On the other hand yield with 0, 25 or 50kg P$_2$O$_5$ ha$^{-1}$ was found to be 1.99, 2.14 and 2.28t ha$^{-1}$ respectively. Also in the year 1989, Sharma et al. observed an increase in seed yield when 18kg N ha$^{-1}$ was applied. Singh et al. (1989) found that reduction in recommended fertilizer rate i.e. 18kg N ha$^{-1}$ and 40kg 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 120kg N + 60kg P$_2$O$_5$ ha$^{-1}$ for wheat and 80kg N + 60kg P$_2$O$_5$ ha$^{-1}$ for rape seed.
Chapter II

Alloush et al. (1990) at the University of Leads in UK observed mineral nutrition of NO$_3$ or NH$_4$-N. Plants were grown for 24 days in water culture under two regimes of nitrogen nutrition (NO$_3$-N and NH$_4$-N) with or without Fe. For plants fed with NO$_3$-N, Fe stress severely depressed fresh weight while little difference in growth was observed in NH$_4$-N fed plants. Typical pH changes were measured in the nutrient solution of the controlled plants in relation to nitrogen supply. The pH increased with NO$_3$ and decreased with NH$_4$-N nutrition. In NO$_3$ fed plants, the uptake of nutrients was reduced by the stress but proportionally NO$_3^-$ and K$^+$ were most affected. Total anion uptake was depressed more than that of cation. 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. Saxena and Rewari (1991) observed the influence of phosphate and zinc on growth, nodulation and mineral composition under salt stress. Results revealed that Zn$^{2+}$ at 5 ppm and phosphate at 20 and 40 ppm improved the growth and nodulation at salinity levels of 4.34 and 8.3 dS m$^{-1}$. The shoot nitrogen content of plants treated with 5 ppm Zn$^{2+}$ and 20 ppm phosphate was equal to that of non-saline control.

Yanni (1992) at Sakha Agricultural Research Station, Egypt studied the performance of chickpea, lentil and lupin nodulated with indigenous or inoculated *Rhizobia* under nitrogen, boron, cobalt and molybdenum. They reported increased nodule weight, plant dry weight, N-content seed yield, seed size and the N and P contents of seed with application of these nutrients. However, a slight decrease in the number of nodules was observed with their application.

Yahiya and Samiullah (1995) at Aligarh observed that leaf area, shoot dry weight and rate of acetylene reduction was significantly increased with the application of phosphorus and 40 Kg P$_2$O$_5$ ha$^{-1}$ increased the concentration in shoots and roots, soluble sugar contents in nodules and shoot N accumulation however, the P concentration in nodules was not affected by different levels of P. At the same place, Inam 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 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 40kg 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 nitrogen levels of 0 and 100kg 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 higher nitrogen level.

Yadav and Srivastava (1997) at Morena (MP) in a field trial gave 0, 20, 40 or 60kg P$_2$O$_5$ ha$^{-1}$ with and without seed inoculation with phosphate solubilizing bacteria (PSB). Highest yield was given by 60kg P$_2$O$_5$ ha$^{-1}$+PSB followed by 60kg P$_2$O$_5$ alone. Similarly, Gupta et al. (1998) also in Madhya Pradesh under field conditions, inoculated the seeds with Rhizobium and Bacillus or uninoculated giving 0-40kg P$_2$O$_5$ ha$^{-1}$ as single super phosphate (SSP) or 40kg P$_2$O$_5$ as rock phosphate. It was observed that seed yield was more with inoculation. Application of 40kg P$_2$O$_5$ given as SSP produced the maximum seed yield. Inoculation and phosphorus application also increased the N and P uptake and seed crude protein content.

Patel (1998) performed a field experiment under irrigated conditions of Madhya Pradesh. The crop was given 0–60kg P$_2$O$_5$ ha$^{-1}$ and various combinations of 20kg N, seed inoculation with Rhizobium and foliar application of 2% diammonium phosphate (DAP). Mean seed yield was highest with 60kg P$_2$O$_5$. The combined application of 20kg N + seed inoculation with Rhizobium + foliar application of 2% DAP gave the highest seed yield. Sonboir and Sarawagi (1998) at Raipur (M.P) gave different combinations of 0–60kg P$_2$O$_5$ ha$^{-1}$, phosphate solubilizing bacteria (PSB), Rhizobium and trace elements. Highest seed yield was found under the treatment 60kg 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 PSB alone or in combination with Rhizobium. Seed yield was increased
by the use of PSB and *Rhizobium* alongwith phosphate fertilizers. Guhey *et al.* (2000) also from Raipur reported an increase in seed protein content with increase in phosphorus levels.

Braga and Vieira (1998) at Coimbra (Brazil) in a field experiment inoculated seeds of chickpea with *Bradyrhizobium* or not inoculated and given 0 or 30kg N ha\(^{-1}\), 0 or 40g 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* giving 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 and 75kg P\(_2\)O\(_5\) produced the highest seed yield and nitrogen. Sheokand *et al.* (1998) conducted experiment in which chickpea was inoculated with *Rhizobium* and raised in sand culture under natural conditions with nitrogen free nutrient solution and 45 days old plants were treated with 20 and 50 mM KNO\(_3\) and sampled at 2 and 6 days after treatment. KNO\(_3\) application induced premature nodule senescence. The mass of green nodules increased by 35% under these treatments and thus was accompanied by a rapid decline in leghaemoglobin content being 51-67% lower than control. The changes were associated with the rapid decline of N\(_2\)-fixing activity. However, the decline in the total soluble sugars was relatively minor as compared to acetylene reducing activity.

Joseph and Sawarkar (1999) utilized the low grade rock phosphate in meeting the phosphorus requirement by amending with farmyard manure (FYM, at 5t ha\(^{-1}\)), pyrites (at 40kg ha\(^{-1}\)) and phosphate solubilizing bacteria (PSB) at Jabalpur (M.P) and found an increase in biomass with increasing level of phosphorus. Application of RP amended with FYM resulted in the highest concentration of P from 80-160 kg ha\(^{-1}\) 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 60kg P$_2$O$_5$ ha$^{-1}$ then nodulation, pods plant$^{-1}$, seeds and stover yield were increased. Combined inoculation of *Rhizobium* and PSB + 60kg P$_2$O$_5$ gave the maximum seed yield and net returns.

Bhuiyan *et al.* (1999) at Rangpur (Bangladesh) reported that seed yield, nodulation, nodule weight shoot weight and stover yield were highest with *Rhizobium* + P + K + Mo + B. 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. El-Hadi and El-Sheikh (1999) in Sudan, studied the effect of seed inoculation with *Rhizobium* and nitrogen @ 50kg ha$^{-1}$. *Rhizobium* inoculation or nitrogen fertilizer application significantly increased the total nodule number, 100 seed weight, yield and protein content of seeds.

Baalbaki *et al.* (2000) in Lebenon, investigated the mechanism of salt tolerance and ionic relation of chickpea cultivars with different nitrogen sources. N-source significantly affected shoot K$^+$/Na$^+$ ratio with nodulating plants having lower ratios than non nodulating plants indicating that *Rhizobial* infection or nodule formation may lead to salt entry curtailing selective ability of chickpea roots. 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. Biofertilizer and phosphorus interaction showed significant influence on growth and P uptake compared with either of the components applied separately.

At Cairo (Egypt), Abo-Shetaia and Soheir (2001) while working on yield and its components in response to phosphorus fertilization reported that P$_2$O$_5$ at 40kg feddun$^{-1}$ significantly increased the pods, pod weight, seed yield and seed and straw yield feddun$^{-1}$. Sawires (2001) at Giza (Egypt) found that 23.25kg P$_2$O$_5$ feddun$^{-1}$ recorded the highest number of pods, pod weight and seed and straw yield. Kurdali *et al.* (2002) at Damascus (Syria) evaluated the impact of three rates of potassium (0, 75
and 150 kg K_2O 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.

Fan et al. (2002) at the department of soil science and plant nutrition in China studied the relation of nitrate uptake, nitrate reductase activity (NRA) and net proton release and compared in 5 grain legumes grown at 0.2 and 2 mM nitrate in nutrient solution. Nitrate treatment imposed on 22 d-old fully nodulated plants lasted for 21 days. Increasing nitrate supply has no significant influence on the growth of any of the species but yellow lupin (Lupinus lutens) had a higher growth rate than the other species. NRA increased with the increased nitrate supply with majority of NRA being present in shoots. Field pea and chickpea had much higher shoot NRA than the three lupin species. Nitrate absorbed by plants, must be reduced to ammonium before incorporation into amino acids. Nitrate reduction is catalyzed by nitrate reductase and nitrite reductase. There are large difference among species of genotypes in the role of shoot and root system in reduction nitrate (Andrews, 1986; Wallace, 1986; Chalifour and Nelson, 1988).

Kurdali et al. (2002) conducted pot experiments to study the impact of 0, 75 and 150 kg K$_2$O ha$^{-1}$ on nodulation, dry matter production and nitrogen fixation. The plants were also subjected to soil moisture regimes: low, 45-50%, moderate 55-60% and high 75-80% of field capacity. Plant species differed in this response to the fertilizer as a means of enhancing growth and overcoming stress condition. The higher level of K-fertilizer increased both dry matter and total N$_2$ fixed in faba bean, but did not have any impact on chickpea. Ahmad et al. (2002) evaluated the effect of salinity and nitrogen on two gram varieties with three salinity and four nitrogen levels. The results revealed the increase in the plant height with increasing amount of urea under 3.5 dS m$^{-1}$ while at higher salinity level plant height showed retrogressive effect and pod number per plant were maximum when 60 and 75 kg ha$^{-1}$ of urea was applied.

Kumar et al. (2003) at Hissar reported the effect of P and K fertilizers, alone and in combination under moisture deficit condition. Phosphorus and potassium were
applied at the rate of 50 kg 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 of fertilizers also proved effective in terms of grain yield. Earlier Tomar et al. (2002) at Junagadh also noted the effect of 0, 25, 50, 75 and 100 kg ha⁻¹ potassium on two varieties of chickpea. 50 kg K₂O ha⁻¹ increased the grain and straw yield, 100 seed weight, protein content and concentration of K and N in grain and straw.

Tufenkei et al. (2005) conducted a study to investigate the effect of *Glomus intraradices* (Arbuscular Mycorrhizal Fungus = AMF) inoculation together with phosphorus and nitrogen on some plant characteristics and nutrient content of chickpea. The results revealed the significant increase in the growth and the contents of nitrogen, phosphorus, iron, manganese and copper with the increasing doses of nitrogen and phosphorus. Kayan and Adak (2006), in Turkey determined the effects of different soil tillage method, weed control and phosphorus fertilizer doses on yield and its components. The grain phosphorus content was significantly affected by phosphorus levels and it was reduced by the highest phosphorus level of 90 P₂O₅ ha⁻¹.

Arya et al. (2007) conducted a study of integrated application of fertilizers with organic compost and biofertilizers at Kanpur. The results revealed that the integrated nutrient application (INA) 50% recommended dose of fertilizer (RDF) + FYM at 5 t ha⁻¹ + biofertilizers significantly enhanced the average plant height, crop biomass, leaf area index, number and dry weight of root nodules. INA further resulted in the production of more grain and biological yield of chickpea and also significantly increased the NPK content in shoot and grain.

Togay et al. (2008) observed the effect of sulphur, phosphorus and *Rhizobium* inoculation under Eastern Turkey conditions. Sulphur @ 0, 50 and 100 kg ha⁻¹ and phosphorus @ 0, 40 and 80 kg ha⁻¹ and inoculation (un-inoculated) were applied. The highest grain yield was reported from 80 kg ha⁻¹ P followed by 100 kg ha⁻¹ S. Gan et al. (2008) in Canada determined the synergistic effect of water stress and N-fertilization on the biochemical properties of nodules, biomass partitioning among shoot, root and nodules and seed yield in chickpea. The crop grown at various rates of N-fertilizer under 90% field capacity (high), 60% (medium) and 30% (low) moisture
level showed significant effect of N and moisture on nodulation and productivity. The use of N-fertilizer reduced the negative effect of water stress by partitioning more biomass to roots and the stronger root system allowed the plants to absorb more water for the transport of fixed N and further stated that the yield losses from ineffective nodulation due to water stress could be minimized with the use of low doses of fertilizer N.