CHAPTER II. LITERATURE REVIEW

The use of sewage wastewater in agriculture has a long history and is receiving renewed attention in the light of increased global water scarcity. It is currently used to irrigate agricultural crops in Middle East, North and South Africa, South America, Asia, Australia, and in parts of Europe (Bastian, 2006). Countries and regions in which water reuse is on the rise include the US, Western Europe, Australia, and Israel (Miller, 2006). Therefore, in this review attempt has been made to include the literature related to the studies made worldwide on the effect of wastewater on wheat and some other crop plants.

Wheat makes high demand for nutrient elements from the soil and N, P and K are considered to be of prime importance as these are absorbed and utilized in larger quantities. However, wastewater cannot meet the high nutrient requirement of the crop and thus, supplemental fertilizer needs to be added to get the optimum yield. Therefore, the role played by NPK in the growth and yield of wheat was also taken into account. It may be pointed out that work on wheat in respect to NPK fertilizers abounds, therefore only some of the recent references have been reviewed in the end of this chapter to give an idea about the nutritional requirement of wheat when grown without wastewater.

2.1 Effect of Wastewater on Wheat

Day et al., 1974 conducted experiment at Tucson, Arizona to study the effects of treated municipal wastewater on growth, total fiber, acid-soluble nucleotides, total protein and amino acids in hay obtained from wheat. Plants grown under wastewater developed culms with larger diameter and higher total fiber content compared to plants receiving well water and recommended dose of N, P and K. Maximum hay
was recorded when wheat was grown with wastewater, followed by hay produced with well water and N, P, and K in amounts equal to those in wastewater, and hay grown with well water plus recommended dose of N, P, and K, in decreasing order. They noted that wheat grown with well water along with N, P, and K in quantity equal to those present in wastewater and hay produced with wastewater alone have similar quantity of total protein, and more than the hay grown with well water plus recommended dose of N, P, and K. Amino acids like alanine, gysine, phenylalanine and tyrosine were also present in higher concentrations in hay obtained with wastewater than in hay produced with remaining two treatments. Day et al., 1975 further performed an experiment to study the effects of treated municipal wastewater on protein and amino acid content of wheat grain. Irrigation treatments included well water plus suggested amounts of N, P, and K; well water plus N, P, and K from commercial sources in doses equal to those present in wastewater; and wastewater from an activated sludge sewage plant. The average number of heads and grain yield was more in plants grown under wastewater. Grain from the plants irrigated with wastewater had more total protein, alanine, histidine, isoleucine, and proline than obtained from other treatments. They concluded that treated municipal wastewater was an effective source of irrigation water and plant nutrients for the production of better quality grain. In continuation another attempt was made by them in 1979, when they studied the effects of irrigating wheat with a mixture of pump water and wastewater and with pump water alone. They reported that in large fields, wheat grown with the pump water-wastewater mixture had taller plants with more lodging, lower grain volume-weights, and higher grain yields than the wheat produced with pump water alone.
Campbell et al., 1983 at Tooele in Utah, studied the long-term effects of municipal wastewater on agriculture land and some crops like wheat, alfalfa and sweet corn. Plants grown on effluent-irrigated sites gave higher growth rate, dry weight, and yield than grown at control sites. Metal concentrations observed in plant and soil were below the toxic level and in fact high P levels were reported in effluent irrigated soil. Ajmal and Khan, 1984 at Aligarh (India) while taking wheat and pea with breweries effluent noted 100% germination under 25%, 50%, and 75% effluent, while it was 80% and 90% in pea and wheat, respectively in 100% effluent. Makki et al., 1987 while observing the effect of drainage water of Al-Hassa in Saudi Arabia, on five field crops like wheat, alfalfa, sweet corn, ryegrass and soybean concluded that seed germination, plant height, root length, leaf area and dry matter were significantly decreased when the plants were irrigated with drainage water. However, the tolerance to drainage water appeared to be beneficial for the growth of wheat which showed significant increase in plant height, root length, leaf area and dry matter accumulation with the mixture of irrigation and drainage water in the ratio of 1:1. Through this study they suggested that drainage water could be successfully reused in cultivation of wheat in conjunction with irrigation water. In 1988, Chakrabarti and Chakrabarti, from Nagpur (India) reported the effect of irrigation with raw and differentially diluted sewage and primary settled sewage-sludge on wheat plant growth, crop yield, enzymatic changes and trace element uptake. They observed an increase in the concentration of some metals, Cu, Zn, Cr, and Mn and decrease in the activities of some enzymes, aspartate amino transferase, alanine amino transferase and peroxidase in different fractions of wheat plants, however, grain yield was not decreased. While large scale cultivation of wheat, sugarcane, paddy, onion and groundnut 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).

Sharma and Habib, 1995 at Bareilly (India) studied the effect of rubber factory effluent on different cultivars of five rabi crops viz. wheat, gram, pea, mustard and barley. 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 and crude protein was significantly lower in seeds of the effluent treated cv. 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 wheat, gram, cowpea, 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⁻¹.

Aziz and Inam, 1995 from Aligarh (India) while studying the quality of sewage wastewater for irrigation and its effect on soil and six crops (wheat, mustard, cauliflower, spinach, cucumber and radish) reported that soil irrigated with sewage showed no significant changes in pH, elemental carbon, organic carbon and some of the cations. On the other hand the soil as well as the crops showed accumulation of some heavy metals in general and the accumulation of Pb, Cr, and Ni in particular was in higher amount in all crops except wheat. Leaves accumulated more heavy metals and inorganic chemical constituents as compared to grains, stems and roots of all crops tested. Aziz et al., 1996 also conducted a field study adjacent to the Mathura
oil refinery. Mathura (India) and observed the long term effects of petrochemical industry wastewater on six crops namely wheat, triticale, chickpea, lentil, summer moong and pigeon pea. They noted that treated wastewater irrigation increased the seed yield of all the crops except the summer moong.

Singh et al., 1995 observed that pre-sowing irrigation with distillery effluent having BOD of 4600 mg l$^{-1}$ had no adverse effect on the germination of wheat, maize, sorghum and cowpea. Later, Singh and Bahadur, 1995 also reported that wheat, maize, rice, mustard, black gram, pigeon pea, soybean and chickpea seeds germinated normally in 20% distillery effluent; whereas green gram seeds germinated normally even in 50% effluent. While wheat seeds were reported to be more sensitive and did not germinate in 50% effluent.

At Riyadh in Saudi Arabia, Hussain et al., 1996 while investigating yield and nitrogen use efficiency (NUE) of wheat under field conditions using well water and treated effluent concluded that higher grain yield and NUE of wheat crop could be achieved with low application rates of nitrogen if the crop is irrigated with treated effluent having nitrogen in the range of 20 mg l$^{-1}$ and above. During the year, 1998, Jovanovic et al., from South Africa reported the possible use of lime-treated acid mine drainage wastewater for irrigation of wheat, maize, soybean, sorghum, pearl millet, cowpea, rye, oat, triticale, ryegrass, lucerne, fescue, crownvetch, cocksfoot, milkvetch, weeping love-grass, smuts finger, kikuyu, panicum and Rhodes. Considerable increases in yield of wastewater irrigated crops were observed, compared with rainfed cropping. Shallow rooting depths were, however, recorded for most of the crops but no symptoms of foliar injury were noted. Iqbal and Mehta, 1998 at Jaora (India) reported that sugar mill effluent increased the dry matter in
wheat, where as chlorophyll content and dry matter of chickpea was adversely affected. In the following year 1999, Pathak et al., at Sitapur (India) studied the effect of distillery effluent and observed that soil amended with effluent increased the grain and biomass yield of wheat and rice grown in sequence as compared to control. Their results also indicated significant improvement in soil properties like available organic carbon, potassium, saturated hydraulic conductivity, bulk density and volumetric water content.

Dhafer et al., 2000 from Italy, reported the impact of wastewater complementary irrigation in comparison to well water with added fertilizer – on growth, water consumption and yield of durum wheat. They observed increase in yield of crop and developed suitable wastewater irrigation techniques for maximum production and avoidance of soil and ground water pollution. Also in the year 2000, El Hameed et al., from Egypt, investigated the extent of contamination hazards in soils and wheat plants resulting from long-term irrigation with sewage water. Their results revealed that prolonged use of sewage water decreased the dry matter weight as well as weight of 1000 grain weight. Concentration of Fe, Mn, Zn and Cu was increased and also, accumulation of Pb, Cd and Ni in the different parts of wheat plants increased with the increasing period of irrigation. Tonk et al., 2000 conducted an experiment at Hisar (India) and reported that the dry matter yield of wheat and uptake of N, P and K increased significantly with the increased supply of industrial wastewater discharged from the glue industry and nitrogen.

Feizi, 2001 from Korea, while examining the effect of treated wastewater on accumulation of heavy metals in wheat, maize, tomatoes, cucumber, alfalfa and soil revealed in their observation that though the heavy metal concentration in the soil and
plants were slightly higher in irrigation with effluent, but no significant heavy metal risk was associated with irrigating the crops using treated wastewater.

Kumawat et al., 2001 at Ujjain (India) 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. Nan and Cheng, 2001 from Baiyin city, China, reported the accumulation of Cd and Pb in spring wheat grown in calcareous soil irrigated with wastewater obtained from two streams viz. Dongdagou and Xidagou which accept both domestic wastewater and some industrial sewage. Zadhoosh and Fardad, 2001 at Karaj (Iran) performed an experiment using in and outflow from water refinery to investigate the effect of wastewater irrigation on wheat. The treatments included: non-refined wastewater (in flow), primary pool water (semi-refined), refined (out flow), and well water. They observed that highest average grain yield and 100 grain weight was with the non-refined treatment, while the lowest with the refined water treatment.

Singh et al., 2002 at Allahabad (India) conducted an experiment to assess the agro-potentiality of the pulp and paper mill effluent on growth, yield and quality of wheat. Three types of irrigation were included; 100% effluent (undiluted), 50% effluent and 0% effluent. They observed increase in chlorophyll content, plant height, shoot and root biomass, grain yield, protein, carbohydrate and lipid content in wheat grains with diluted effluents, while undiluted effluent caused inhibition in plant growth resulting in a sharp decline of yield.
Hayat et al., 2002 at Aligarh (India) studied the role of oil refinery wastewater on heavy metal content of soil and the two crops (wheat and mustard). They reported that heavy metals in soil, water and grains were within the permissible limits and also, seed yield in wheat and mustard, irrigated with wastewater, was more than that grown with ground water. Javid et al., 2003 also from Aligarh, noted the impact of sewage wastewater discharged from the sewage treatment plant of the AMU on wheat cv. HD-2329 and concluded that its application promoted the growth and also enhanced the yield but protein and carbohydrate were lower in grains of wastewater grown plants.

Agrawal and Sachan, 2003 from Valsad (India) reported the effect of sugar industry wastes (sugar industry effluent, sugar industry sludge and pressmud) on growth and their residual effects on soil. They noted significant increase in plant height, fresh and dry weight of shoot, though there was decrease in germination percentage and none of the treatments of irrigation was found to significantly change the soil properties. Therefore, it was concluded that effluent could be used as a good sources of P, and K whereas the sludge and the pressmud could serve as potent sources of N, P, K, and organic matter without much adverse effect on soil. Choukr-Allah et al., 2003 at Cairo (Egypt) performed an experiment to stabilize rainfed wheat yield with supplemental irrigation using treated wastewater. Maximum yield was obtained when 70% of supplementary irrigation (175 mm) was given at the flowering period.

Casa et al., 2003 from Italy, reported the effect of enzyme-treated olive mill wastewater (OMW) on durum wheat. They observed that when wheat seeds were irrigated with treated OMW, germinability was increased by 57% at 1:8 dilution and
by 94% at 1:2 dilution, as compared to the same dilutions using untreated OMW. Similarly, effect of OMW on durum wheat was also reported by Rinaldi et al., 2003 from Italy. According to their three years studies, OMW without pre-treatment when spreaded on crop during vegetative stage produced necrosis in leaves and caused a slow emergence of secondary stems, however, at this stage, the crop showed good capability to recover, hence, plant dry matter accumulation was not significantly influenced by non-treated OMW. No significant differences, neither for grain nor for straw yield, were highlighted between the treated and non-treated OMW. Cereti et al., 2004 from the same country, investigated the reuse of microbially treated olive-mill wastewater as fertilizer. They tested several types of OMW with or without rock phosphate, microbially treated or not, and concluded that the beneficial effect on seed weight, spike number and kernel number was maximum after using the treated OMW.

Sukanya and Meli, 2004a from Karnataka (India) reported the effect of distillery effluents on wheat. The treatments included six dilutions; effluent:borewell water (1:5, 1:10, 1:25 and 1:50); undiluted effluent; and only borewell water. They noted that N, P, K, Zn, Cu, Fe and Mn in soil were higher in plots irrigated with undiluted effluent than those irrigated with other treatments. The crop total nutrient uptake and crop yield were maximum with 1:50 dilution. While the grain yield decreased progressively with the decrease in dilution levels. Dilution at 1:50 also gave the maximum number of productive tillers, ear length, ear weight, number of grains ear\(^{-1}\), 1000 grain weight and harvest index. The undiluted effluent treatment adversely affected biomass production, and nutrient and water uptake, thus recorded lower yield. In continuation, they (2004b) further investigated the effect of the same effluents as N source on the yield and quality of wheat. The treatments were: 100% N
substituted through liquid or solid effluent; 50% liquid + 50% solid effluents; 50% liquid or solid effluent + 50% inorganic N source; 25% liquid or solid effluent + 75% inorganic source; and 100% through inorganic source. They obtained maximum grain and straw yields with 50% solid effluent + 50% inorganic source, followed by 25% solid effluent + 75% inorganic source and 100% inorganic source. The treatment 50% solid effluent + 50% inorganic source gave the maximum sedimentation value, dry gluten and wet gluten due to high protein content. Comparatively higher values of soil N, P, and K were obtained by them through the use of 100% distillery wastewater.

Kaushik et al., 2005 studied the role of different concentrations in the range of 0-100% textile effluents (untreated and treated) collected from H.P. cotton mill Ltd., Haryana (India) on seed germination, delay index, shoot and root length, plant biomass, chlorophyll and carotenoid contents of three cultivars of wheat. Their data revealed that textile effluent did not show any inhibitory effect on seed germination at low concentration (6.25%) and the other parameters also followed the same trend. They also noted that seeds germinated in undiluted effluents did not survive for longer period.

Nazari et al., 2006 from Iran, investigated the effect of industrial sewage sludge and effluents on the concentration of some nutrients, heavy metals and dry matter yield of wheat, barley and maize. Well water, well water + sewage sludge @ 50 tonnes ha⁻¹ and three industrial effluents from Polyacryl factory were tested. Their data showed the micronutrient and heavy metal concentrations in plant tissues were higher using the effluents and sewage sludge in comparison to well water. The dry
matter yield of roots and shoots was maximum using well water + sludge in comparison with well water and effluents which increased the shoot dry matter yield.

The effect of untreated and treated olive mill wastewater (OMW) on seed germination, plant growth and soil fertility was studied by Mekki et al., 2006 from Tunisia. Wheat, tomato, chickpea, bean, and barley were tested for germination index and growth in soil irrigated with OMW. The results showed beneficial effect of using treated OMW and the plants showed an improvement in seed biomass, spike number, plant growth and 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. Similarly, Brunetti et al., 2007 from Italy, reported the effects of amendment with treated and untreated olive oil mill wastewaters on soil properties, soil humic substances and durum wheat yield. In this study, two types of irrigation, lagooned water (LW) or catalytically digested wastewater (CW) at two levels were used. Both LW and CW increased the soil EC, total organic carbon, total extractable carbon, humified and non-humified carbon forms, available P and K. However, in comparison to LW-amended soil, CW-amended soil featured more contents of total extractable carbon and humified carbon. Addition of LW and especially CW, affected the grain yield positively by increasing the number of kernels per unit area, spike density and kernel weight.

While working on the physicochemical properties of treated distillery effluent from the Lords distillery, Ghazipur (India) Pandey et al., 2007 performed an experiment to assess the effect of various concentrations of effluent ranging from 0%, 25%, 50%, 75%, and 100% on seed germination of three selected crops i.e. wheat, pea and okra. They reported higher value of TS, BOD, and COD in distillery effluent.
than recommended by Bureau of Indian Standards, indicating its acidic nature with high dissolved salts and organic matter. They noted that germination percentage decreased with increasing concentration of wastewater in the three seeds tested, whereas the germination speed, peak value and germination value increased up to 50% concentration only, however, above 50% effluent concentration, it had an adverse effect.

To determine the effect of tannery wastewater on some germination properties of wheat, maize, rice, chickpea, bean, sunflower and soybean seeds the study was conducted by Tayyar et al., 2008 in Turkey. 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.

Chandra et al., 2009 at Unnao (India) investigated the accumulation and distribution of toxic metals in wheat and mustard irrigated with distillery and tannery effluents. According to their analysis, effluents and soil samples had high metal contents than the permissible limits. Further analysis indicated high accumulation of Fe, Mn, and Zn. Hence, they concluded that wheat and mustard irrigated with untreated effluents possessed health hazards.

2.2 Effect of Wastewater on Plants

Ajmal and Khan, 1983 at Aligarh (India) studied sugar mill effluent on kidney bean and pearl millet. Their studies found that germination was quicker in the control and with 25% effluent in comparison with higher concentrations. Ajmal and Khan, 1984a also assessed the impact of vegetable ghee producing effluent on kidney bean and pearl millet where 100% effluent decreased the germination of kidney bean, while
pearl millet showed an increase compared to control. 25% effluent promoted the
growth of kidney bean whereas pearl millet showed better response with 50%, 75%,
and 100% effluent. They also tested the suitability of industrial dairy processing
effluent on pea and mustard (Ajmal et al., 1984b). In yet another study during the
year 1985a, Ajmal and Khan collected textile industry effluent and applied it on
kidney bean and okra where 50% effluent proved better for both the crops.
Germination was delayed in 100% effluent and it was 90% under 75% effluents.
They (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. It was concluded that only diluted effluents proved favourable for plant
growth.

Impact of municipal wastewater and sewage sludge on the growth of coriander
and spinach was reported by Iqbal et al., 1994 from Pakistan. According to their
studies, highest crop weight and biomass were harvested with treatment comprising a
medium of 1:2 fine sand and cattle manure, irrigated with sewage water as compared
to fine sand and irrigation with tap water. The lowest was recorded with treatment, a
medium of 1:2 fine sand and raw sludge, and irrigated with sewage water. Nashikkar,
1994 from Nagpur (India) reported that seed germination of cabbages, aubergines,
okras, and cauliflowers, was retarded with domestic wastewater with high BOD.
However, seedling growth was enhanced by wastewater with medium to high BOD
levels.
Al-Jaloud et al., 1995 from Riyadh (Saudi Arabia) while studying the effect of wastewater irrigation on mineral composition of corn and sorghum concluded that its use did not increase the mineral concentrations of either macro and micro-elements or heavy metals in both crops to hazardous levels according to the established standards and therefore, could be used safely for crop cultivation. Chakrabarti, 1995 at Nagpur (India) noted that application of diluted sewage wastewater with or without nutrient fortification for ten years resulted in build-up of macronutrients in soil, with special reference to nitrogen which was manifested in higher growth and yield of rice, without any other added nutrient. El Mardi et al., 1995 from Oman, worked on the effect of treated sewage water from Sultan Qaboos University campus utilities, on vegetative and reproductive growth of date palm. It significantly increased leaf Na, K and Cu and decreased leaf Ca and fruit Zn contents compared with desalinized water irrigation, but no significant effect was observed on fruit K, Ca, Mg and Na concentrations for the same palm and thus, none of the examined metals found to reach levels toxic to man or plant. Lapena et al., 1995 from Spain, evaluated the possible use of treated municipal wastewater for citrus spp. and concluded that it was suitable for irrigation.

Eid and Shereif, 1996 at Cairo (Egypt) observed the effect of wastewater irrigation on growth and mineral contents of barley, broad bean and rape under greenhouse. The dry matter yield was maximum from raw wastewater mixed with fresh water (1:6). The content of P, N, Mn, and Ni increased significantly with mixed wastewater compared to fresh water. However, the concentration of heavy metals in plants was lower than the critical level. Phytotoxic effect of industrial and sewage wastewater on sunflower plants was studied by Gadallah, 1996 in Egypt, reporting its
detrimental impact on growth, chlorophyll content, transpiration rate and relative water content. Similarly, studies carried out in Spain by Burlo et al., 1997 where severe adverse effect of municipal wastewater was observed on loquat plants as they suffered foliar necrosis and all of them died at the end of the experiment.

Aziz et al., 1998 at Aligarh, while examining the performance of triticale under five levels of irrigation with treated effluent (TE) of Mathura oil refinery, reported three irrigations with TE proved better to four levels of ground water, showing linear increase in all the parameters studied. However, lower protein and carbohydrate contents were noted under TE. In continuation (1999) while studying the effect of the same wastewater on corn, mustard and soil, it was noted that properties of soil showed no significant changes, whereas TE irrigation resulted in increased growth and yield of both crops. Shahalam et al., 1998 from Jordan, tested the impact of wastewater irrigation on soil and lucerne, radish and tomato. Their results showed that yield obtained from the wastewater with fertilizer was compatible with that of the use of fresh water with fertilizer. The fruit skins were free from viable faecal coliforms 24 hours after the wastewater application. Similarly, Srikantha et al., 1998 at Bangalore (India) while studying the effect of undiluted and diluted dairy effluent on yield and nutrient composition of French bean and amaranthus, observed that germination percentage decreased with increase in the quantity of effluent used during irrigation. Even dry matter yield was highest with control and lowest with raw effluent.

Hussain and Al-Saati, 1999 reported that use of treated wastewaters in Saudi Arabia as a supplemental irrigation has not only increased crop production, water use and nitrogen use efficiencies but also served as a source of plant nutrients. The short-
and long-term use of different types of wastewater for irrigation did not show any significant increase in the bioaccumulation of heavy metals in crop as well as in soil. Ruple et al., 1999 from Florida, reported the feasibility of using electrodialysis reversal reject (EDR) water to supplement the traditional wastewater effluent for turfgrass (ryegrass) irrigation and to assess the effect of reject water on growth of bermudagrass. They irrigated with four mixtures of reject:effluent (0:1, 1:2, 2:1 and 2:0), and noted no significant difference in the yield of bermudagrass but reduction in ryegrass in all proportions indicated potential problems while using reject water for irrigation. Also working on turfgrasses, Mortram, 2003 from UK, evaluated the effect of wastewater while conducting the pot experiment and reported that biomass and shoot length was significantly more in turfgrass irrigated with wastewater than distilled water.

Murillo et al., 2000 while studying the response of olive tree to irrigation with wastewater from the table olive industry in Spain, reported that wastewater affected the trees adversely and significant reduction in olive yield was recorded, indicating the unsuitability of this kind of wastewater for olive orchards. Rebolli et al., 2000 from Spain, indicated in their studies on treated sewage wastewater, that no detrimental effects were found after using wastewater for irrigation of young citrus trees, therefore, reclaimed wastewater proved to be a suitable alternative water resource for irrigation without reducing the yields. In California, Shannon et al., 2000 analyzed the salt tolerance in leafy vegetables irrigated with saline drainage water and reported that Swiss chard was the most salt tolerant, followed by radicchio. Greens, kale, pac choi, and to lesser extent, tatsoi, have potential as winter-grown leafy vegetables in drainage water reuse systems. Segura-Perez et al., 2001 also from
Spain, studied the use of purified and ozone-treated wastewater to fertigate melon had positive effects on the addition of fertilizer salts since the application of total N and K was decreased by 40.8% and 17.8%. Analysis of heavy metals in soil and plant (leaf and fruit) and microbiological analysis of fruits indicated no contamination. Braddock and Downs, 2001 from Australia, while irrigating sugarcane with sewage wastewater recorded significant increase in cane yield by 45% and also saving of sufficient amount of fertilizers up to 100 tons of N and 35 tons of P annually.

Malavizhi and Rajamnnar, 2001 conducted experiments at Madurai (India) to study the effect of sewage effluent on forage yield and quality of bajra-napier hybrid grass. They reported that sewage effluent irrigation in interaction with 100 kg N ha\(^{-1}\) increased the green fodder, dry fodder and the crude protein yield was found to be highest. Chang, 2002 from China, also studied the effect of cattle farm wastewater on napier grass and reported that irrigation of 19500 m\(^3\) ha\(^{-1}\) year\(^{-1}\) (identical-to 450 kg N ha\(^{-1}\) year\(^{-1}\) ) of anaerobic treated wastewater significantly yielded more fresh grass weight than application of chemical fertilizer. Crude protein contents were also significantly higher with wastewater then the control. Dzhalalzade, 2003 from Russia, has seen the effectiveness of irrigating silage corn with wastewater. According to the studies, wastewater had positive effect not only in terms of an increase in green mass yield but also the quality of crop, obtaining high digestible protein hectare\(^{-1}\). Freitas et al., 2004 from Brazil, reported that higher productivity may be obtained with swine wastewater, which increased the plant height, spike index, height and weight of spikes in maize for silage. Mohammad and Mohammad, 2004 from Jordan, observed the effect of irrigation of forage crops (maize and vetch) with treated wastewater which resulted in increased yield of the two crops. They
concluded that secondary treated wastewater could be a source of plant nutrients and can be reused for irrigation. Weinberg et al., 2004 (Israel) reported that forage crops irrigated with secondary-treated wastewater were suitable for animal feeding.

Erfani et al., 2002 (Iran) conducted field study to investigate the effect of irrigation with treated municipal wastewater on lettuce. Yield was highest under irrigation with wastewater over all growing seasons as compared to control whereas, maximum fresh weight was obtained from irrigation with well water and cattle manure. Lone et al., 2003 from Pakistan, reported the adverse effect of sewage water irrigation on okra and spinach as Ni, Cd, Pb, and Cr concentration was much higher than the permissible level recorded in edible parts with the application of sewage water and a mixture of tube well and sewage water as compared to control.

Doddamani et al., 2003 from Karnataka (India) reported that irrigation with distillery effluent alone at lower concentration remained ineffective in increasing the yield of sunflower crop and beyond 50% it was harmful to the crop. However, dilution of effluent up to 50% along with the fertilizer application, recorded significantly higher seed yield and oil content. Gupta and Shukla, 2003 while observing the physicochemical properties of sewage water from Chachar nala, Allahabad (India) also studied its effect on seed germination and seedling growth on cowpea and okra. The highest germination and growth was recorded at 25% concentration of sewage water. From 50% and 100% concentration, the germination and growth were lower than the tap water.

Javid et al., 2003 at Aligarh, reported the efficiency of both sewage wastewater and thermal power plant wastewater in improving the vegetative growth, physiological characteristics and yield of black gram. Khan et al., 2003 further
studied the same sewage wastewater and reported that wastewater application on spinach and methi increased the total chlorophyll content, photosynthetic rate, growth and yield of the two crops. Shah et al., 2004 also reported the effectiveness of the same water in improving the yield and quality of triticale. Akhtar et al., 2006 further observed advantage of using thermal power plant wastewater as a source of irrigation for the cultivation of linseed as it improved the growth, seed yield and oil content of the crop over ground water. Later during the year 2007a, Tabassum et al., reported the utility of city wastewater as source of irrigation for mustard crop and while working on the same water, they (2007b) also recorded higher yield in lentil as compared to ground water.

Al-Lahham et al., 2003 (Jordan) while investigating the effect of different treatments of potable and treated wastewater on quality of tomato fruit concluded that microbial contamination increased exponentially with increasing proportions of treated wastewater application and it was advised to apply treated wastewater as an alternative of irrigation for tomatoes consumed only after cooking, but not for use as raw. In further studies, effect of treated municipal wastewater for irrigation of tomato was reported by Najafi et al., 2003. The results showed that surface drip irrigation and subsurface drip irrigation with treated wastewater gave the maximum productivity, much above the control. They also reported that since these treatments had lesser contact between effluent and plants, therefore, little scope for microbial contamination appeared.

Samples of various vegetable plant species, namely okra, chard, celery, Jew’s mellow, lettuce, onion, radish, rocket and spinach were collected from the fields at Mostord in Egypt by Abdel-Sabour and Rabie, 2003 where the soils have been
subjected to prolonged domestic and industrial wastewater irrigation, and tested for heavy metal accumulation. Analysis of edible plant parts revealed that the use of wastewaters significantly increased the concentration of tested metals which was exceeding the permissible limits. Hamdard et al., 2005 from Pakistan, reported that Pb and Cd accumulation in turnip, tomato, fenugreek, long melon and radish grown with sewage effluent were slightly higher from those irrigated with canal water. However, the accumulated Pb and Cd were within permissible limits. Similarly, Kakar et al., 2005 studied the phyto-accumulation of heavy metals in tomatoes grown on city effluents at Quetta city, Pakistan. They reported that concentration of Fe, Mn, Zn, Cu, Pb, and Ni in plants was above the toxic levels and hence, city effluents were not suitable for growing vegetables. In Zimbabwe, the study was conducted by Muchuweti et al., 2006 to check the heavy metal contents of crops irrigated with mixtures of sewage wastewater. The crops maize, bean, pepper, tsunga and sugarcane analyzed were found to be heavily contaminated with Cd, Cu, Pb, and Zn, moreover, this contamination was at its highest, much above the permissible limit, in the two staple dietary crops i.e. maize and tsunga. While studying the impact of wastewater on spinach in the suburban areas of Varanasi (India) Sharma et al., 2007, concluded that the use of treated and untreated wastewater for irrigation increased the contamination of Cd, Pb, and Ni in edible parts of vegetables causing potential health risk in the long term. No adverse effect of sewage wastewater use on the overall element concentrations in soil and on water spinach was reported by Marcussen et al., 2008 at Hanoi (Vietnam).

Economic benefit from irrigation with treated municipal wastewater was studied by Tsadilas and Vakalis, 2003 in Greece. From the data of their study, it was
concluded that treated wastewater can be used for the irrigation of corn and cotton, saving fresh water as well as fertilizers and also obtaining the same or even better economic results. Similar results were obtained from the studies of Papadopoulos and Savvides, 2003 on impact of treated municipal wastewater on green pepper, eggplants and sudax, indicating the superiority of the treated wastewater to borehole water and its ability to produce higher yield with less N fertilizers. Ahmad et al., 2003 from Aligarh (India) reported that sugarcane crop gave better response to the oil refinery treated wastewater than ground water, enhancing cane length, fresh weight and yield. In another studies, Hayat et al., 2007 on the same wastewater, suggested that it also favours the growth and productivity of pigeon pea and no adverse effect on the legume-Rhizobium symbiosis was observed.

Effect of untreated OMW and olive pomace compost on ryegrass was studied by Montemurro et al., 2004 reporting an increase in growth parameters with the highest untreated OMW application and indicating possible use of OMW as an amendment to ryegrass. No accumulation of heavy metals in the soil was observed. El Hassani et al., 2009 of Morocco, conducted studies to investigate the changes in viability, biomass production, essential oil yield and essential oil composition of spearmint when exposed to OMW. They reported that the short contact of raw OMW with mint cuttings caused an irreversible damage in rhizogenesis and shoot developments. However, in a field experiment, spearmint showed a good capability to recover when OMW was spread at 81 m$^2$ at vegetative phase of growth and also, a slight increase of mostly of the mint essential oil constituents was obtained. But when the dose applied was 161 m$^2$, phytotoxicity was expressed by a significant reduction in biomass as well as essential oil yield.
Rija et al., 2005 (Pakistan) revealed that irrigation with sewage wastewater caused a significant increase in total protein, carbohydrate and chlorophyll contents of chickpea, mung bean and lentil. In Saudi Arabia, Al-Fredan, 2006 recorded the maximum improvement in growth of faba bean with 100% municipal wastewater effluent without any nutrient deficiency, or signs of toxicity. During the same year, Burun et al., from Turkey, reported that when the lime-stabilized urban wastewater was applied to soil, grain yield and nutrient content of barley increased considerably. No negative effect on protein content was noticed by them. In Brazil, Cavallet et al., 2006, while conducting out experiment to study the impact of enzyme industry wastewater on maize, reported an increase in grain yield and concluded that wastewater of enzyme industry may replace soil mineral fertilizer for the same crop. Similarly, Kiziloglu et al., 2007 from Turkey, reported that treated wastewater application increased yield and also N, P, K, Fe, Mn, Zn, Cu, Bo, and Mo contents of cabbage plants. Undesirable side effects were not observed in plant heavy-metal contents. Esmailiyan et al., 2008 from Iran, reported positive influence of municipal wastewater on grain yield and its components of corn as compared to fresh water. Contrarily, Qishlaqi et al., 2008 also from Iran, assessed the negative impact of wastewater irrigation on soils and crops (lettuce, spinach and celery) and concluded that it lead to change in soil quality (pH, OM, Ex-Ca), increase in heavy metal concentration in soil (notably Ni and Pb) and crops (Cd and Ni) and thus posing potential health risk through consumption of affected vegetables.

Studies of Palese et al., 2009 from Italy, revealed that low-quality treated wastewater can be useful for olive plantation irrigation as no significant microbial contamination was recorded on fruit harvested directly from the canopy of the
wastewater-irrigated trees and also, contaminations on fruits sampled from the ground in the wastewater-irrigated plot were always low and usually similar to, or lower than those observed on drupes collected from the rainfed plot. Zavadil, 2009 from Czech Republic, tested the effect of municipal wastewater on the yield and quality of lettuce, radish, carrot, potato and sugar beet. Contrary to secondary-treated wastewater, the primary-treated wastewater significantly increased the yield of all vegetables. However, secondary-treated wastewater increased only the sodium content in radish and carrot whereas primary-treated wastewater significantly increased the sodium content in consumable parts of all vegetables and nitrate contents in lettuce and radish.

Dhanam and Arulbalachandran, 2009a applied effluent obtained from Briquetting and Carbonization plant, Tamilnadu (India) on groundnut. Seed germination, seedling growth, fresh and dry weight of seedlings as well as photosynthetic pigments, sugar, protein, aminoacid and phenolic contents showed the increasing trend up to 10% concentrations of effluent. However, the increased concentrations of effluent were toxic. They (2009b) further investigated the effect of fluorine effluent, on the same crop and observed that morphological and biochemical parameters decreased with the increase in effluent concentrations except 10% effluent. While observing the effect of the same effluent on another crop, black gram, they (2009c) again found that all the growth parameters increased up to 10% concentration whereas decrease from 25% onwards was observed. Similarly, Lenin and Thamizhiniyan, 2009 also from Tamilnadu, reported that germination characters, root and shoot length, fresh and dry weight and pigment content of hyacinth bean increased up to 5% concentration and thereafter declined with higher concentrations.
of spent wash effluent discharged as wastewater from juice factory. Thamizhiniyan et al., 2009 irrigated black gram and ragi with sugar mill effluent and concluded that effluent concentration above 5% was toxic for both crops and it can be used for irrigation purpose only after appropriate treatment and dilution.

2.3 NPK Fertilizers and Wheat

Jena and Bechra, 1998 from Orissa (India) reported that closer spacing of 15 cm between rows, seed rate @ 150 kg ha\(^{-1}\) and application of 120-66-40 kg, N-P\(_2\)O\(_5\)-K\(_2\)O ha\(^{-1}\), respectively, increased the grain yield as compared with wider spacing, low seed rate and farmer’s use of low fertilizer rate. Lomako, 1998 from Russia, obtained optimum yields of winter wheat with supply of 70:120:120 NPK before sowing, and subsequent dressings of 100 N at early spring and 30 N at heading. Higher protein and gluten contents were also achieved under these conditions. According to the studies of Azad et al., 1998 at Jammu (India) with each successive increase in fertilizers rate, 100%NPK i.e. 100 kg N + 50 kg P\(_2\)O\(_5\) + 25 kg K\(_2\)O ha\(^{-1}\) and 125 or 150% NPK with or without 20 kg Zn ha\(^{-1}\) and/ or 10 tons farm yard manure (FYM) ha\(^{-1}\) recorded a significant increase in growth and yield. However, FYM in conjunction with various fertilizer doses gave a significant increase in yield. Buttar and Singh, 1998 while working in Punjab (India), reported increase in grain yield with the application of P with no significant difference between rate (20, 40, 60 or 80 kg P\(_2\)O\(_5\) ha\(^{-1}\)) or source (NPK or liquid ammonium polyphosphate). Spike development, plant height and dry matter yield also increased with increasing P dose. Auti et al., 1998 at Rahuri (India), while conducting field experiment with four levels of N, P\(_2\)O\(_5\) and K\(_2\)O kg ha\(^{-1}\) i.e. 30:15:15, 60:30:30, 90:45:45 and 120:60:60 and five sources of fertilizers, reported that application of 120:60:60 kg NPK recorded the maximum
number of productive panicles, length of panicle, number of spikelets panicle$^{-1}$, number of grains panicle$^{-1}$, grain weight and 1000 grain weight.

Karczmarczyk et al., 1999a from Poland, while observing response of spring wheat and triticale to irrigation or no irrigation and 0, 300 or 450 kg NPK ha$^{-1}$, concluded that supplemental irrigation and higher NPK rates increased the grain yield. In addition, chlorophyll and carotenoid content, photosynthesis, transpiration, leaf conductance and activities of enzymes like nitrate reductase, acid phosphatase and peroxidase were also increased. In another study on the influence of irrigation and 0, 150, 300 or 450 kg NPK ha$^{-1}$ on three cultivars of spring wheat, they (1999b) also reported that grain and straw yield without irrigation was highest with 150 kg NPK ha$^{-1}$, while with irrigation the yield increased with the increasing fertilizer rates. Koszanski et al., 1999 further observed that irrigation and increased fertilizer rates increased the leaf area, tillering, culm height and 1000 grain weight. Gwal et al., 1999 of Madhya Pradesh (India) while taking different combinations of 0-0-0, 60-30-30, 120-30-30 or 180-90-90 kg N-P$_2$O$_5$-K$_2$O ha$^{-1}$ fertilizers and four cultivars of late-sown wheat noted that plant height, number of tillers plant$^{-1}$, spike length, grain protein content, grain yield and straw yield were increased with NPK rates. Thakur et al., 1999 at Samastipur (India) under field conditions studied the effect of organic manure, fertilizer level and seed rate on yield and quality of wheat and reported that 100:50:25 kg NPK ha$^{-1}$ recorded significantly higher grain yield, harvest index and grain protein content than the lower fertilizers levels. However, 10 tons organic manure along with 125% more than the suggested dose of fertilizers further increased the grain yield than the application of fertilizers alone.
While conducting an experiment to determine the integrated use of inorganic fertilizers about low, 70-33-35 kg N-P₂O₅-K₂O ha⁻¹; and high, 100-50-50 kg N-P₂O₅-K₂O ha⁻¹, biofertilizers: phosphert, azofert, bioplin and vitormone and growth regulators: protein hydrolysate on growth and productivity of wheat. Mohiuddin et al., 2000 from West Bengal (India), reported that highest grain and straw yields were obtained with Biopiin and protein hydrolysate at high fertilizer levels. Nehra et al., 2001 from Haryana (India) reported that among the organic manure treatments, maximum values for all the attributes studied were observed with vermicompost and among inorganic fertilizers, increasing dose of nitrogen improved the leaf area index, photosynthetic pigments, photosynthetic rate, effective tiller number, grains ear⁻¹, grain and straw yields and dry matter. Maximum values were recorded with 120 kg N + 60 kg P₂O₅ + 60 kg K₂O ha⁻¹. However, nitrogen at 120 and 90 kg ha⁻¹ + Azotobacter were statistically at par with recommended dose of NPK. Effect of organic matter resources and inorganic fertilizers was also studied by Singh et al., 2001 on yield and nutrient uptake in the rice-wheat cropping system at Kanpur (India). While Bansal et al., 2001 of Madhya Pradesh (India) reported that potassium applied in two splits have extra advantage over basal application and also, fertilizer dose of N₁₀₀ P₅₀ K₅₀-₅₀ resulted in highest yield. To classify the most important nutrients affecting growth and water use efficiency of wheat and to improve the grain yield, Liu et al., 2001 conducted experiments in China and reported that N application improved all the growth parameters and also increased the grain yield by 64%. The application of P increased the yield by 17%, while N together with P further increased the total dry weight and grain yield by 48 and 75%, respectively. However, K application had no such effect. YongLin et al., 2001 also from China,
applied NPK (300:500:100 kg ha$^{-1}$) alone or combined with organic manure (OM) and reported increase in wheat spike length, grains spike$^{-1}$ and plant height, thus enhancing the biomass and grain yield, however, NPK combined with OM had a better yield-increase than the NPK alone. Berecz. 2001 from Hungary, reported that farmyard manure (30 tons ha$^{-1}$) resulted in significantly lower grain yield as compared to 40:20:0 NPK kg ha$^{-1}$. Baking quality was also unfavourable with under-fertilized treatments. The highest fertilizer rate (160:80:120 NPK kg ha$^{-1}$) gave the optimum results.

Rusu et al., 2001a from Romania, in their nitrogen rate experiments showed that P and K fertilizers applied without N did not always increase the yield, but there were positive response to NPK which varied with soil and other fertilizer treatments. In continuation (2001b), the results of their phosphorus rate experiments (0, 30, 60 and 90 kg P$_2$O$_5$) were applied together with 50 kg N + 30 kg K$_2$O ha$^{-1}$ or 100 kg N + 60 kg K$_2$O ha$^{-1}$ revealed that crop yield increased with P application but fertilizer response was greater on the chernozem soil than the luvisol. They (2001c) also worked out the potassium rate (0, 40 and 80 kg K$_2$O ha$^{-1}$) together with 50 kg N + 30 kg P$_2$O$_5$ ha$^{-1}$ or 100 kg N + 60 kg P$_2$O$_5$ ha$^{-1}$ with or without 10 t manure ha$^{-1}$, and reported that the best yields were obtained with 40 kg K$_2$O ha$^{-1}$, although on luvisol wheat yield increased with the higher K rate when more N and P was applied.

Investigations into the effect of three N, P and K levels were also carried out at Faisalabad (Pakistan) by Hussain et al., 2002 where different NPK levels significantly affected growth, yield and quality, but the highest grain yield was recorded under 105-75-75 kg NPK ha$^{-1}$. Kulhare, 2003 from Madhya Pradesh (India) investigated the effects of FYM and NPK rates and observed that 100:60:40 kg ha$^{-1}$ NPK significantly
increased the plant height, tillers, ear length, numbers of grains ear\(^{-1}\), grain and straw yield compared to no treatment and 50% of recommended dose. However, FYM + 100% NPK rate produced a higher yield than the recommended rate alone. Similarly, Rawat and Pareek, 2003 from Rajasthan (India) reported that application of 10 tons FYM and 120+50+40 kg N, P\(_2\)O\(_5\) and K\(_2\)O ha\(^{-1}\) significantly increased the grain and straw yields. According to the studies of Pandey et al., 2004 application of 150, 75 and 50 kg N, P and K ha\(^{-1}\) together with 175 kg seed ha\(^{-1}\) was the best for obtaining higher grain and straw yield of surface-seeded wheat under lowland rice ecosystem of North Bihar (India). While evaluating bread wheat under different fertilizer levels, Rajput et al., 2004 from Pakistan, reported that the combinations of 160-80-50 and 180-90-50 kg NPK ha\(^{-1}\) produced satisfactory grain yield and thus could be recommended in their local agro-climatic conditions.

Sahay and Singh, 2004 from Bihar (India) while investigating the effect of cropping and nutrient use reported that NPK + lime fertilizer treatment gave the higher grain yield which was obtained even after 46 years of continuous cropping, however, inorganic fertilizers combined with farmyard manure at half-dose gave the highest grain protein content. Dewangan et al., 2004 from Chattisgarh (India), carried out an experiment on various levels of fertilizer (30:30:20, 60:45:30 and 90:60:40 kg ha\(^{-1}\) N, P\(_2\)O\(_5\) and K\(_2\)O) under 2, 4 and 6 irrigations and obtained increased number of effective tillers, number of grains per plant, grain and straw yield with increasing irrigation and fertilizer levels.

Combined effect of NPK and water on spring wheat yield was also worked out by ZhengHu et al., 2004 in an arid desert region of Shapotou (China). N and P fertilizers significantly influenced the yield, characterized by increase of the yields by
increasing supply of N and P fertilizers; however, K has a less influence. During the same year, ShuZhang et al., also from China, reported that highest grain yield was obtained with long-term application of N, P and K at a ratio of 1:1:1 (120 kg ha$^{-1}$) and the highest protein content with 120 kg N ha$^{-1}$. On the other hand, the lowest grain yield was obtained without fertilizer while lowest protein content with 60 kg N + 60 kg P ha$^{-1}$. The effect of long-term fertilization treatments on leaf photosynthetic characteristics and grain yield was also studied by Jiang et al., 2004 from the same country, reporting that with the treatments of combined organic manure and inorganic fertilizers (TMI), net photosynthetic rate, maximal activity of photosystem 2, chlorophyll content of flag leaf and LAI were much higher, compared with the treatments of only inorganic fertilizers (TII), which resulted in different grain yields in TMI and TII. Among the TMI or TII, both flag leaf and canopy photosynthetic abilities and yield levels increased with the supplement of NPK fertilizers, except for the treatment of NK. Similarly, Huan et al., 2004 while studying the effect of long-term fertilizer use on wheat in grey desert soil reported that combination of NPK with farmyard manure is important to improve the soil fertility, yield and quality of wheat. Field experiments were also conducted by XiaoBing et al., 2005 where fertilizer application consistently increased the yield with the addition of NP and NPK fertilizers. Also, the highest protein yields were achieved in NPK and NPK+N treatments. Similarly, MingBiao et al., 2005 concluded that fertilizer application promoted the root growth, increased the grain yield and also improved the grain quality, however, NPK fertilizers in combination with organic fertilizer further improved the grain quality.
Singh et al., 2005 from India observed that conjunctive use of organic manures and balanced inorganic fertilizer use produced maximum and sustainable crop yield and also maintained the soil fertility and productivity. Also in the year, 2005, Bojovic and Stojanovic of Serbia, investigated in their studies that chlorophyll and carotenoid contents in all cultivars tested by them, were lowest with unfertilized soil and the variant of fertilization with N and P turned out to be most favourable. The next most favourable variant was with nitrogen alone, and it was followed by the variant with N and K.

Singh et al., 2006 at Kanpur (India) noted that number of spikes, their length, grains spike\(^{-1}\), grain weight spike\(^{-1}\), 1000 grain weight, grain and straw yield increased with increasing rates of NPK fertilizer along with 5 tons FYM ha\(^{-1}\). While investigating the effect of soil conditioners and fertilizer doses under rice-wheat cropping system, Singh et al., 2006 also from Kanpur (India) were of the opinion that application of recommended dose of NPK gave maximum grain and straw yield, and every reduction in fertilizer doses from 100 to 75% and 75 to 50% decreased the grain yield. Khandwe et al., 2006 of Madhya Pradesh (India) while working on vermicompost and NPK, reported that application of 100% recommended NPK rates gave the highest values of grain and biological yield. Similarly, Khan et al., 2006 from Pakistan, recommended that NPK @ 120-90-60 kg ha\(^{-1}\) + FYM @ 10 tons ha\(^{-1}\) + wheat crushed straw @ 10 tons ha\(^{-1}\) for maximum yield.

While investigating the fertilizer requirement of wheat in recently reclaimed soils, Mehdi et al., 2007 also from Pakistan, revealed that by the application of each increment of N fertilizer, there was increase in grain and straw yield where as P and K had non-significant effect except P at higher rate and K at lower rate. However, the
optimum dose suggested by them was 175-105-60 kg ha\(^{-1}\) as N, P\(_2\)O\(_5\) and K\(_2\)O respectively.

More recently, the productivity and seed quality of wheat in response to irrigation regimes and nitrogen levels were evaluated by Gharib et al., 2009 from Sudan. They reported that application of 86 kg N ha\(^{-1}\) (480 kg NPK ha\(^{-1}\) in the ratio of 18:18:5) coupled with the 7-14 days irrigation intervals significantly improved seed germination, seedling vigour and gave the highest grain yield. Seeds with higher storability up to 12 months were also produced under above mentioned treatments. Similarly, according to the studies of Ali et al., 2009 from Pakistan, application of half of recommended N (128 kg ha\(^{-1}\)) just after first irrigation and remaining half just after second irrigation gave maximum grain yield and harvest index.

Hence, the last section of the review makes clear that wheat in general makes a high demand for nutrient elements from the soils, which are recuperated only to a very limited extent by natural processes. Therefore, if the yield of wheat is to be increased, and especially the high yields of new improved dwarf varieties are to be maintained and augmented, balanced amounts of plant nutrients have to be added to the soils to make up the deficiencies. Response of wheat to the application of nitrogenous fertilizers alone has been found to be almost universal, but the responses invariably vary with the fertilizer used: NPK>NP>N; the responses also varied according to the magnitude of nutrient deficiency of the soils. The net returns, however, may improve with optimum use of fertilizers.