Review of literature

2. REVIEW OF LITERATURE

A search through the literature of previous studies having the aim of the present investigation in focus was done and the relevant reports have been listed out.

Environmental Pollution

Greman *et al.* (2003) observed that widespread contamination of agricultural lands, has significantly decreased the extent of arable land available for cultivation worldwide. Bridge (2004) has stated that organic or inorganic pollutants, severely impact human health, productivity of agricultural lands and the sustainability of natural ecosystems. Most of the industries dump their hazardous effluents and pollute different water bodies. These effluents contain suspended or dissolved solids, which have adverse effects on human health and environment (Begum *et al.,* 2010).

Improving the Environmental Quality with Green Belts

The expansion of ornamental tree green belts in and around the industrial complexes and in the city, helps in reviving the ecological balance and improves environmental quality (Hassan *et al*., 2008; Tabari *et al*., 2008; Farroq, 2010). The increase in tree plantations raises the production of commercial timber and fuel (Singh and Bhati, 2004; Saadat *et al*., 2009). The ornamental tree production compared to other types of crops, requires a large amount of nutrients which are already presented in waste water, this in turn permits their build up by self-treatment of waste water through the irrigation (Lubello *et al*., 2004). The woody species consequently reduce pollution of the receiving water bodies. They help in reducing the toxicity of soil and safeguard the food chain because of the uptake of heavy metals through their extensive root system (Tabari *et al*., 2008; Saadat *et al*., 2009).

Tanneries and Tannery Pollution

Though the tanneries are playing an important role in the economic growth of the country, the enormous pollution load along with the toxic nature of waste water makes the tanneries a potential threat to the areas in the vicinity of their locations. Indiscriminate letting out of untreated tannery effluents have caused a great deal of soil pollution having wasted much of the agricultural land and large pockets of land become barren. Due to the addition of such pollutants to the soil, plants come under stress (Chandra *et al*., 2010) and it may affect plant physiology especially seed germination.

Tannery waste water contains a mixture of chemical compounds, which are used during leather processing and are not properly degraded even after the conventional treatment causing a negative impact on living organisms and environment (Alvarez-Bernal *et al*., 2006; Oral *et al*., 2007; Shakir *et al*., 2012; Lofrano *et al*., 2013). More than 250 chemicals (inorganic and organic) are used in the tannery industry in excess of 300 kg of chemicals per ton of hide treated (Buljan *et al*., 2000). Cr (VI) (hexavalent chromium) is one of most problematic pollutants discharged by the tanning industry (Zayed and Terry, 2003; Mant *et al.*, 2006). This industry is of particular concern due to the indiscriminate discharge of metal-rich effluents, toxic sludge and noxious gases into adjacent environmental compartments causing considerable environmental damage (Tariq *et al*., 2006).

The tannery industry also uses large amount of salt, sodium chloride, for the pickling of leather and hides that makes soil sodic when discharged into the environment without treatment. High concentration of soil salinity can cause water deficit, ion toxicity, and nutrient deficiency which leads to molecular damage and even plant death (Maggio *et al.,* 2010).

Heavy Metal Pollution in the Environment

Heavy metal pollution due to industrial effluents is gaining worldwide attention (Mishra *et al*., 2008). Metal effects on plants thriving on these soils become inevitable (Edwards, 2002; Jabeen *et al.*, 2009). The metals are present in the wastewater/effluent of different industries such as electroplating, metal cleaning, mining, plating baths, paper and pulp, paint, refineries, textile and tanneries (Mistry *et al.*, 2010). Water used in these industries creates a potential hazardous waste in our environment because of the introduction of various pollutants such as heavy metals into soil and water resources (Prabavathy and De, 2010). Contamination of agricultural soil by heavy metals has become a serious environmental concern due to their negative impact on crop growth and ecosystems (Ruan and Da Silva, 2011; Lokhande and Suprasanna, 2012; Zhang *et al*., 2013). The examined tannery effluents contained environmentally unwanted heavy metals and dissolved solids in excess quantities (Ali *et al*., 2013).

Chromium Toxicity in Plants

Plants take up the minerals and other nutrients present in the soil where they grow. While most of the plants are susceptible to heavy metals present in the environment, certain plants show no toxicity to specific heavy metals present in the soil. These plants could accumulate heavy metals without any harm to them and are called accumulators. The plant *Crotalaria juncea* L. chosen for the study is a known accumulator of chromium (Agarwal *et al*., 2014).

Presence of chromium beyond the tolerance limit (< 2 ppm) makes water unsuitable for crop growth (Sahu *et al*., 2007). Cr (VI) is equally toxic to plants and affects various aspects of plant metabolism, such as chlorosis and necrosis in plants, alter enzymatic functions and can cause ultra-structural modifications in cell membrane (Panda and Patra, 2000; Cervantes *et al*., 2001; Dixit *et al*., 2002). Cr (VI) compounds are toxic, mutagenic and even carcinogenic in nature and remain stable for several months in the soil without changing the oxidation state. Cr (VI) is accumulated by plants and is biomagnified at different trophic levels through the food chain (Kotas and Stasicka, 2000; Gupta and Sinha, 2006; Gupta *et al*., 2011).

The consumption of edible products derived from effluent-fed agriculture puts consumers to health risks (Karanja and Njenga, 2010). Metal accumulated in vegetables is toxic and even in small concentrations causes health risk such as cancer, mutation or miscarriages (Arfaoui *et al.,* 2005).

In plants, inhibition of plant growth and alteration of physiological and biochemical characteristics due to chromium was observed by Sharma *et al*. (2003); Panda and Choudhury (2005). Chromium blocks the photosynthetic electron transport, inhibits photophosphorylation and decreases membrane integrity (Shanker *et al.,* 2005), affects nitrogen and protein metabolism (Caravaca *et al.,* 2003). Since Cr enjoys structural similarity with other essential elements like iron (Fe) and sulphur (S), it interferes with the uptake of these elements (Gardea-Torresdey *et al.,* 2005) leading to mineral imbalance. High concentration of Chromium exposure caused chlorophyll breakdown and membrane permeability and an increase in membrane damage (Vajpayee *et al.,* 2000; Davies *et al.,* 2002; Bertrand and Poirier, 2005; Shanker *et al.,* 2005; Choudhary and Panda, 2005; Panda and Choudhary, 2005; Vernay *et al.,* 2007). Chromium exposure results in complete loss of growth in lateral roots while lesser concentration starts damaging root cap, stomata, cotyledonary hairs seem to be collapsed and plasma membrane appears to be detached from the cell wall under cytological studies (Mariappan *et al.,* 2001). Cr (VI) toxicity can reduce seed germination and radicle growth in plants due to inhibition of cell division by inducing chromosomal aberrations (Jain *et al*., 2000). It also interferes with several metabolic processes like reduced growth, chlorosis, and ultrastructural effects on organelles, chromatin condensation, swelling of mitochondria which leads to plant death (Dazy *et al.*, 2008). Hexavalent chromium is more phytotoxic than trivalent chromium, and it retards growth by reducing the number of palisade and parenchyma cells. It also increases the vacuoles and creates dense material along the xylem and phloem walls (Han *et al.*, 2004).

Metals (trace elements) are beneficial for plant growth and physiology, after excessive uptake by plants, these elements may participate in some physiological and biochemical reactions that can destroy normal growth of the plant by disturbing absorption, translocation, or synthesis processes. Therefore, the growth and procreation of the plant is prohibited and leads to death (Wei and Zhou, 2008).

Treatment of Tannery Wastewater

Treatment of tannery wastewater is expensive; so many developing countries use a primary and secondary treatment which may include biological and physicochemical processes such as, ion exchange resins (Kocaoba and Akcin, 2002), reverse osmosis (Hafez *et al.*, 2002), an electrolysis system (Vlyssides and Israilides, 1997) and chemical removal systems such as precipitation, coagulation and adsorption. These methods however, are either expensive or produce secondary pollution in the environment and often not considered as cost effective for small scale tannery industries. As a result the land suffers the contamination from the tannery effluent which ultimately takes the toll of soil productivity.

Soil Bioremediation

Wastes from domestic, agriculture, urban and industrial sources are the main cause of soil pollution (Tiwari, 2002). Mondal and Saxena (2005**)** reported that chemicals such as sodium chloride, sodium carbonate, sodium bicarbonate and calcium chloride based in tanning causes the alkalization of soil resulting in the increased pH of the soil. Addition of such chemicals when pollute the soil, plants come under stress and the plant physiology is affected (Kumar and Ghosh, 2013). It is reported that growth and yield of plants grown in soil using raw effluents for irrigation has been considerably decreased (Mythili and Kathikeyan, 2011). The purpose of soil bioremediation is not only to enhance the degradation, transformation, or detoxification of pollutants, but also to protect the quality and capacity of the soil to function within ecosystem boundaries, to maintain environmental quality and sustain biological productivity (Adriano *et al*., 1999; Adriano, 2001). An approach towards good soil management, with an emphasis on the role of soil inhabitants like earthworms, in soil fertility, is very important in maintaining ecosystems (Shuster *et al.*, 2000; Ansari and Kumar, 2010; Elumalai *et al.,* 2013).

Phytoextraction

Phytoextraction may be termed as the extraction of toxic elements present in the soil using plants. For this the accumulator plants are used. Bio remediation with phytoextraction is a popular technology. In India the farmers are known to sow different crops in a cyclic manner to increase the productivity of the soil.

Plant-based environmental remediation approaches have attracted attention for several years by academic and industrial scientists as a low-impact clean-up technology, ability to improve soil conditions, in the context of various contamination scenarios in both developed and developing nations (Raskin and Ensley 2000; Robinson *et al.*, 2003). Plants are important component of the ecosystems as they transfer the metals from abiotic into biotic environments (Chojnacka *et al.*, 2005). *C. juncea* has been shown to be a natural metal hyper accumulator that can accumulate and tolerate high metal concentrations in its roots and leaves and thus has great potential for phytoremediation, a green technology for removing toxic metals from the environment (Pereira *et al.,* 2002).

Plant Growth Analysis

Plant growth analysis is required to explain the differences in plant growth in terms of differences between species growing under same environmental condition or differences within a species growing in different environments. Plant growth analysis is considered to be a standard method to study the plant growth and productivity (Wilson, 1981). Growth and productivity are functions of a large number of metabolic processes, which are affected by environmental pollution and other genetic factors.

Experimental Plant Material

The experimental plant material used in the present study is Sunnhemp (*Crotalaria juncea* L.) an important legume used as a summer crop for green manure. It is adapted to dry conditions and grown worldwide because of its very high nitrogen-fixing potential. It also protects soils against erosion, reduces soil compaction, promotes nutrient recycling, suppresses pathogens, weeds and nematodes and supplies high quality fibre for manufacturing specialized paper products (Wang *et al.*, 2009). Mulching of *C. juncea* (Fabaceae) can improve soil structure, reduce soil erosion, and increase levels of soil organic matter and nutrients (Sharma *et al.*, 2010). Agronomically, White and Haun (1965) considered this plant as a promising new annual pulping material for the United States. Favourable properties cited were (a) little or no need for nitrogen fertilization, (b) ability to grow on poor soils and (c) drought resistance. Using such a leguminous cover crop has been proven to meet nitrogen demand for various crops (Reeves *et al.,* 1996; Marshall, 2002). Some strains are able to resist nematode infestation also.

The indigenous practice of fibre extraction from the stem of *C. juncea* and other species by retting is a very tedious process. Scarcity of water in areas where it is grown and intensive labour demand are two main reasons for decreasing interest of the farmers for cultivation of sunnhemp in different parts of India (Bhatt *et al.*, 2008; Pandey *et al.*, 2010).

Biofuel using *C. juncea*

Another practical application of *C. juncea* includes fuel (Cantrell *et al.*, 2010). In fact, a process optimization method for the extraction of oil from *C. juncea* is being tried out to utilize the fuel value in *C. juncea* (Rotar and Joy, 1983; Dutta *et al.*, 2015). Sunnhemp biomass is used for bioethanol production which will reduce the crude oil consumption (Narasimhulu and Manasa, 2018) and also environmental pollution.

Plant Growth Regulators and its Effect on Plant Growth

In general Plant Growth Regulators (PGRs) are organic compounds, which bring about an increase in growth or modification of growth in plants. Growth regulators, when added in small quantity as foliar sprays, modify the natural growth of the plants, right from seed germination to senescence in crop plants. Among them the use of Gibberellic acid (GA) and Naphthalene acetic acid (NAA) is of considerable interest in different fields of agriculture. Sachs and Lang (1957) reported that GA regulates cell division and elongation. The effect of gibberellins on internode tissue of *Phaseolus vulgaris* was studied by Feucht and Watson (1958) and they reported that growth substances like GA and NAA caused increase in height of *Phaseolus vulgaris.* Kaufman (1965) reported that growth substances like GA and NAA caused increase in height of the plant. Fathima and Balasubramanian (2006) studied the effect of growth regulators on the exo-morphological characters of

Abelmoschus esculentus. The effect of plant growth regulators on the quality of bast fibres in *Hibiscus sabdariffa* was also studied by Fathima and Balasubramanian (2006). Studies on various crops have indicated the beneficial effects of growth regulators on crop growth, fruit yield, seed yield and seed quality (Manjunathprasad *et al*., 2008). Aloni *et al*. (1990) has shown that IAA and GA_3 control the differentiation of primary phloem fibres in the stem of *Coleus blumei*.

Biofertilizers and its Effect on Plant Growth

Organic farming helps to provide many advantages such as eliminating the use of chemicals in the form of fertilizers/pesticides, recycling and regenerating waste into wealth; improving soil, plant, animal and human health; and creating an eco-friendly, sustainable and economical bio-system model (Ansari and Ismail, 2001). Bio-fertilizers have shown a good promise and have emerged as an important component of Integrated Plant Nutrition System. Bio-fertilizers improve the physical properties of soil, organic carbon, soil tilth and health in general and enhance nutrient utilization, efficiency and grain quality. They are cheaper and pollution free and their production is based on the renewable energy sources as pointed out by Tewatia *et al.* (2007).

Earthworms and Soil Fertility

Earthworms live in an environment filled with different varieties of pathogens. Vermiwash has potent antimicrobial activity. Earthworm survival in environment has caused the development of efficient defence mechanisms against various environmental pathogens during the course of evolution, including the production of certain anti-microbiological substances, especially active proteins and enzymes (Wenli *et al*., 2011). Apart from this the candidature of earthworms for land restoration, soil fertility maintenance, soil pollution bio monitoring, waste water treatment and plant production program is well established (Suthar and Ram 2008; Suthar, 2010). Earthworm processed material called 'casts' contain several soil nutrients in forms which are easily available to plants (Taylor *et al.*, 2003). Kaviraj and Sharma (2003) observed that level of total potassium was increased 10% by epigeic earthworms *Eisenia fetida* during vermicomposting. Bansal and Kapoor (2000) have studied vermicomposting of crop residues and cattle dung with *Eisenia fetida*. Several experiments have proved that worm casts can promote lush growth of plants, which may be due to the presence of plant growth factors like cytokinins and auxins in the worm casts (Gavrilov, 1963).

Vermicompost and Vermiwash as Biofertilizer

Vermicomposting technology involves the bio-conversion of organic waste into vermicasts and vermiwash using earthworms (Bentize *et al.*, 2000; Manyuchi *et al.*, 2012). Atiyeh (2000) reported an increase in root and shoot biomass in tomato plants grown in soil amended with vermicompost. Shweta and Singh (2006) reported the presence of plant growth-promoting substances in vermicompost. Ansari (2008) studied the effect of Vermicompost on the productivity of potato (*Solanum tuberosum*), spinach (*Spinach oleracea*) and turnip (*Brassica campestris*). Vermicomposting of sugarcane bagasse in combination with rice straw and its impact on the cultivation of *Phaseolus vulgaris* was studied by Ansari and Jaikishun (2011).

Vermiwash, the by-product from the vermicomposting process, which is the leachate, has also been reported to be rich in NPK (Nitrogen, Phosphorous, and Potassium) composition (Sundaravadivelan *et al.*, 2011; Quaik *et al.*, 2012; Nath and Singh, 2012). Vermiwash preparation was standardized by Ismail (1997). Recently vermiwash production has drawn the attention of commercial vermiculturists, because of its rich organic composition (Kumar, 2005). Vermiwash has excellent growth-promoting effects and also possesses an inherent property of acting not only as a fertilizer but also as a mild biocide (Ismail, 1997; Ansari, 2008).

As a liquid fertilizer vermiwash is used in organic agriculture both as replacement and supplement for solids and for their unique capacity to provide nutrients effectively and quickly (Hatti *et al.*, 2010). There are a large number of beneficial micro-organisms which help in plant growth and disease prevention (Gulsar and Iyer, 2006). Zambare *et al*. (2008) reported that the vermiwash is an eco-friendly soil conditioner and the microflora present make available inorganic nitrogen, amino acids and inorganic phosphates to plants through ammonification and nitrification processes.

Krishnamoorthy and Vajranabhaian (1986) reported relatively higher ranges of plant nutrients such as ammonia, urea, oxidisable organic matter and exchangeable forms of some essential plant nutrients in vermiwash. They also reported that plant hormones, e.g. cytokinins and auxins are present in earthworm casts. The total available salts were 68% higher and Na (Sodium) content was 97.8% higher in vermiwash as compared to vermicompost. Na can stimulate plant growth and can be used as an alternative in cases where potassium is deficient. The same result was reported by Ansari and Kumar (2010). Antibacterial activity of vermiwash from *Eisenia fetida* earthworms was studied by Govindarajan and Prabakaran (2012) who reported that the *Eisenia fetida* vermiwash has bioactive compounds to inhibit the growth of bacteria. Biochemical characterization of vermiwash and its effect on growth of *Capsicum frutescens* was studied by Varghese and Prabha (2014) and they reported that the liquid manure vermiwash is an effective bio fertilizer.

Physico-chemical and Biological study of Vermiwash

The physico-chemical and biochemical parameters of vermiwash produced from different leaf litters by using earthworm was studied by Sundaravadivelan *et al.*(2011) and Shivsubramanian and Ganeshkumar (2004). Zambare *et al.* (2008) showed that vermiwash contains a cocktail of enzymes like protease, amylase, urease, phosphatase nitrogen fixing bacteria like *Azotobacter sp., Agrobacterium* sp., and *Rhizobium* sp. and some phosphate solubilizing bacteria. Vermiwash contains nitrogenous excretory substances, growth stimulating hormones and nitrogen in the form of mucus (Tripathi and Bhardwaj, 2004).

Influence of Substrates on Vermiwash

Evidences shows that vermiwash has impressive benefits on plant growth, but these benefits are dependent on quality of substrate used to produce vermiwash (Scheuerell and Mahaffee, 2002; Nath *et al.*, 2009). Leaf nutrition with foliar spray of vermiwash obtained from municipal wastes increases the photosynthesis activity, plant physiology and performance of the plants (Astaraei and Ivani 2008). Vermiwash produced by using coconut leaf in crop production capacities of soil was studied by Gopal *et al.* (2010). Nath and Singh (2011) reported the effect of vermiwash obtained from different vermicomposts of animal agro and kitchen wastes on the growth and productivity including flowering periods of different Rabi crops viz. wheat, gram, pea and mustard. Tiwari and Singh (2016) reported that foliar applications of combinations of vermiwash obtained from animal dung and municipal solid waste with bio-pesticides like neem oil (*Azadirachta indica*) and aqueous extract of leaf and bark had positive effect on growth, flowering and productivity of tomato crop.

Vermiwash and Plantgrowth

The foliar spray of vermiwash is a good liquid manure that improves crop productivity (Subasashri, 2003). Nutrients and growth-promoting substances present in the vermiwash influenced its potentiality in seed germination and seedling vigour (Chattopadhyay, 2015). Hatti *et al.* (2010) studied the effect of *Perionyx excavatus* vermiwash on the growth of plants. The effect of vermiwash on kharif crops was reported by Nath and Singh (2012). The positive effect of vermiwash on plant growth is in conformity with the studies of Buckerfield *et al*., (1999). Thangavel *et al*., (2003) who reported that weekly application of vermiwash increased growth and yield in crop plants.

Elumalai *et al.* (2013) have studied the influence of vermiwash and plant growth regulators on the exomorphological characters of *Abelmoschus esculentus.* Karuna *et al.* (1999) have studied the stimulatory effect of vermiwash on crinkle red variety of *Anthurium andraeanum.* Lalitha *et al.* (2000) reported the emphatic effect of plant growth and production by the application of organic fertilizers. Samadhiya *et al*. (2013) reported that the foliar spray of vermiwash on the tomato plants showed a significant growth of plants, increases shoot length and number of leaves. Increased shoot height was recorded in plants involving vermiwash spray. These observations confirmed early studies on *Abelmoschus esculentus* (Lalitha *et al.*, 2000) and on *Spinach oleracea* (Ansari, 2008). Kale (1998) reported that vermiwash as foliar spray was effective in increasing the growth and yield response of *Anthurium andraeanum*. The effect of vermiwash treated soil in which *Spinach oleracea* and *Allium cepa* were grown was found to be significantly higher when compared to control group. No significant effect was observed on the plants of *Solanum tuberosum* (Ansari, 2008). The effect of vermiwash was observed on *Abelmoschus esculentus* by Ansari and

Kumar (2010). The seed yield of *Vigna radiata* was significantly higher with vermiwash compared to water spray (Khairnar *et al*., 2012).

Shivsubramanian and Ganeshkumar (2004) studied the influence of vermiwash on biological productivity of Marigold. Muscolo *et al.*, (1999) found an auxin-like effect on nitrogen metabolism and cell growth in *Daucus carota.* Gajalakshmi and Abbasi (2004) has reported the stimulating influence of vermiwash on root length in *Solanum melongena* L. Ismail (1997) reported that vermiwash can used as a foliar spray, which improves the growth, quality and yield of Okra (*Abelmoschus esculentus*). Gopal *et al.* (2010) stated that application of vermiwash on paddy showed the maximum growth and yield. Giraddi (2003) also reported significantly lower pest population in chilli applied with vermiwash as compared to untreated crops.

Zambare *et al*. (2008) and Varghese and Prabha (2014) showed the potential of vermiwash in sustainable agriculture. It could improve the germination and seedling survival rates in crop plants growing on nutrition depleted soils (Fathima and Sekar, 2014). It could be utilized effectively for sustainable plant production in low input based green farming (Edwards and Arancon, 2004) and it influences significant growth and productivity in black gram (Sobha *et al*., 2003). Weersinghe *et al*. (2006) have suggested that vermiwash is a natural growth supplement for tea, coconut and horticultural crops. Vermiwash when diluted is able to bring about increased germination rate and enhanced seedling growth in plants studied (Anasri and Kumar, 2010).

Vermiwash as Bio Pesticide

Vermiwash contains essential nutrients which enhance the nutrient availability of plants and is considered as a biotic aqua fertilizer. On insects, vermiwash has anti-spawning effects (Zhu *et al.,* 2001). Nath *et al.* (2009) reported that vermiwash amended with phytohormones, enzymes and vitamins improved the growth and productivity of crops and also increased the resistance power of crops against diseases. Different combinations of vermiwash (buffalo dung) and gram bran with neem oil and aqueous extract of garlic is very effective over control for increased growth, early flowering and enhanced the productivity of gram crop upto three times over control (Nath and Singh, 2011; Nath and Singh, 2015). Tiwari and Singh (2016) reported that the foliar application of a combination of vemiwash with neem oil, have increased plant growth in brinjal.

Combined use of vermicompost and vermiwash (5 or 10%) gave higher fresh yield of vegetable pea plant and okra (Mahto and Yadav, 2005; Ansari and Kumar, 2010). Esakkiammal *et al*. (2015) reported that the combination of vermicompost and vermiwash showed maximum positive effects on the growth and yield of lablab beans. Application of vermiwash increases growth, flowering and corn yield characters of gladiolus when they are applied along with recommended fertilizers doses (Kumar *et al*., 2013).

Effects of Industrial Effluents on Seed Germination

The effect of industrial effluents on rice and black gram seed germination and seedling growth has been reported by Niroula (2003). The low amount of dissolved oxygen in the effluent due to the presence of higher concentration of suspended and dissolved solids reduces the energy supply through anaerobic respiration which results into the restriction of growth and development of the seedling (Saxena *et al*., 1986). Changes in osmotic potential due to salt concentration causes delay in germination (Adriano *et al.* (1973); Karunyal *et al*. (1994); Mishra and Bera (1995); Malla (2005)). Mariappan and Rajan (2002) reported that higher percentage of germination in *Parkinsonia acculeata* and *Caesaalipinia coriaria* was observed in lower concentration of the tannery effluent. Altaf *et al.* (2008) and Nath *et al.* (2009) have reported that different concentrations of tannery effluents and increase in concentration of Cr (VI) showed significant reduction in germination percentage, seedling growth, pigments and mitotic index.

According to Reddy and Borse (2001) the salt content outside the seed causes less absorption of water by osmosis and inhibits the germination of seeds, while chromium causes inhibition of cell division and root elongation, thus affects plant growth. Interestingly seedlings in 25% dilution showed maximum values in all the parameters. The effect of fertilizer factory effluent on seed germination, seedling growth on *Arachis hypogaea*, *Glycine max*, *Oryza sativa*, *Sorghum bicolor* and *Vigna radiata* was investigated by Sundaramoorthy *et al.* (2000) and found that the percentage of germination and seedling growth was maximum in the diluted effluent than the control. Rani and Alikhan (2007) reported that the lower concentration of distillery effluent showed higher vigour index in two cultivars (*Cv.Saka-4 and Pusa 44*) of *Oryza sativa*.

Promoting effect of dairy effluent on paddy seed germination, seedling growth and dry matter production was studied by Dhanam (2009). Subramani *et al.* (1998) reported a progressive decrease in seedling growth of cow pea (*vigna unguiculata*) with the increasing concentration of fertilizer factory effluent. Similar findings have been reported by Mishra and Bera (1996). The effect of paper mill effluent on germination of green gram was reported by Malla and Mohanty (2005).

Effects of Industrial Effluents on Plant Growth

Plants undergo significant morphological and metabolic changes in response to metal toxicity (Singh and Bhati, 2004). To evaluate the Cr (VI) toxicity and its accumulation in relation to biomass production, it was found that dry matter production in *Vallisneria spiralis* was severely affected by Cr (VI) concentrations (Vajpayee *et al*., 2001). Srivastava and Singh (1980) revealed comparatively higher CGR (crop growth rate) in podding stage than in early growth stages in different varieties. The injurious effects of effluent of a chemical manufacturing plant on the growth of maize, soybean and wheat was reported by Hewitt and Keller (2003). Similar results were also reported by Yasir (2003), Kilicel and Dag (2006) and Rusan *et al.* (2007). Accumulation of Cr in the roots of Tomato plants and translocation to tomatoes have been reported by Mangabeira *et al.* (2006). The impact of bio pesticide and microbial fertilizers on productivity and growth of *Abelmoschus esculentus* was studied by Lalitha *et al.* (2000).

Industrial effluents with heavy metals adversely affect the growth and development when used for irrigation (Nagajyoti *et al.*, 2008). Kaushik *et al.* (2005) reported that the chlorophyll and carotenoid contents of three different cultivars of wheat did not show any inhibitory effect at low concentration (6.25%) of textile effluent. Rani and Shrivastava (1990) reported that the protein content in peas decreased with increasing concentration of spent wash. The increased activity of the protease or other catabolic enzymes may be due to the degradation in protein content under chromium stress (Rai *et al.*, 1992; Vajpayee *et al.*, 2001). Singh and Agarwal (2009) reported that total chlorophyll and carotene significantly increasing with sludge quantity. Marvari and Khan (2012) reported that total chlorophyll showed a reduction of 72.44% while protein showed a reduction of 71.65%. Chromium mostly in its hexavalent form can replace Mg (Magnesium) ions from the active sites of many enzymes and deplete chlorophyll content (Vajpayee *et al.*, 2000). The internal anatomy of the plant was also affected by heavy metals (Hadad *et al.*, 2008).

Singh *et al.* (2011) reported that tannery waste water at lower concentration promotes the yield of *Chrysanthemum* cuttings. Rajannan *et al.* (1998) reported that the application of spent wash with 50 times dilution in rice resulted in normal yield. There are reports on beneficial effects of diluted municipal sewage on fox foil millet in Iran (Asgharipour and Azizmoghaddam, 2012). Mahimairaja and Bolan (2004) reported that low doses of distillery spent wash remarkably improve the yield of dry land crops like ragi, sorghum, ground nut, and green gram. Effect of distillery effluent on rice and maize was also studied by Pandey *et al.* (2008). Effect of industrial effluent on growth of barley was estimated by Raia and Khan (2010) and emphasized that lower concentration of effluent was harmless.

Random Amplification of Polymorphic DNA

Random amplification of polymorphic DNA (RAPD) is a qualitative method in which changes in nature and amount of DNA can be detected and this technique has been used to identify DNA damage and mutation in plants induced by heavy metals (Enan, 2006; Cenkci *et al.*, 2009; Liu *et al.*, 2012) and waste waters (Nielsen and Rank, 1994; Grisolia *et al.*, 2005; Swaileh *et al.*, 2008). RAPD technique was used as a sensitive, precise, and efficient tool for genomic analysis in *C. juncea* genotypes. The phytogenotoxic assessment of tannery effluent and chromium on *Allium cepa* was studied by Gupta *et al.* (2012). The genotoxic effect of heavy metals was detected by the application of Randomly amplified Polymorphic DNA (RAPD) by Enan (2006) and induced genotoxicity by toxic chemicals in *Phaseolus vulgaris* was studied by Cenkci *et al.* (2009). The detection of tannery effluent induced DNA damage in Mung bean was studied by Raj *et al.* (2014) and they concluded that treated or untreated effluents contain genotoxic substances which cause DNA damage in Mung beans, and thus irrigation using waste water poses health hazard to human and the environment. The wastewater induced genotoxicity in oats (*Avena sativa*) was studied by Swaileh *et al.* (2008) and they obtained bands ranging from 150 bp to 2000 bp by using 15 primers. DNA damage due to chromium exposure was observed in

Vicia faba (Koppen and Verschaeve 1996). Labra *et al.* (2004) reported hyper methylation of DNA and increase in DNA polymorphism in *Brassica napus* in response to Cr (VI) exposure.

Dilution of Industrial Effluents as a Solution

Ramana and Biswas (2002) have stated that tannery effluent can be used for irrigational purpose after proper dilution and can be discharged safely in to the soil. Rajendra *et al*. (2010) has stated that due to the presence of considerable quantities of nitrogen and phosphorus along with some essential elements, the use of waste waters for irrigation is gaining importance. The alternative use of diluted effluent for irrigation not only solves its disposal problem, but also will serve as natural fertilizer for several crops if used at proper concentration. However in the present scenario water has become a costly, rare and cherishable commodity not only for agriculture but also for living beings to survive. Hence acceptance of the above view cannot be taken as a solution for the present day industrial pollution. Hence we should go for the technology of zero discharge of industrial effluents and start reclamation of already spoiled land by using necessary corrective measures.