REVIEW OF LITERATURE
The pertinent literature related directly as well as indirectly to the research topic is being described under the following sub-headings:

2.1. Characteristics of saline and alkaline soils
2.2. Effect of salinity and alkalinity on plants
2.3. Amelioration of saline and alkaline soils
2.4. Studies related to aromatic crops
2.5. Water quality and their effect on soil characteristics and plants

2.1. Characteristics of saline and alkaline soils

Mishra and Gadker (1970) reported that (i) use of saline water for irrigation and (ii) Low permeability water are the main causes for the development of salinity and alkalinity in the Chambal command areas.

Singh and Sharma (1970) reported that the use of water for irrigation at different locations fall into the class of very high salinity and very high sodium class. Silt + Clay, CaCO$_3$, pH and calculated value of ESP, SAR, and SSP of saturation extract were found to be higher in case of irrigated soil as compared to unirrigated soil.

Gopalaswami et al. (1973) reported that the saline alkali soils were less in nitrogen and phosphorus and rich in potassium content. Most of the soil samples were of neutral reaction and harmless in total salt content. Agrawal and Tripathi (1974) reported that exchangeable sodium (ES) was found to be highly correlated with gypsum requirement (GR). This relationship seems closer for sodic soil ($r = + 0.93$). The pH and SAR as an
approximate estimate of ESP were found limited to sodic soils only and consequently, it may not be satisfactory to use pH and SAR as a measure of ESP in saline sodic soil of U.P.

Paliwal and Gandhi (1976) reported that adsorption of sodium slightly increased with the increase of salinity and more with SAR and decreased with Ca: Mg ratio. A lower Ca: Mg ratio enhanced soil sodicity and more of the light textured soil.

Jain et al. (1977) found that the exchangeable potassium does not appear any systematic variability between soils. Calcium and magnesium are less in alkali soil. Copper is found in alkali soil to a range of 0.14 - 0.28 ppm Gunn and Richardson (1979) observed that salt affected soils generally contain appreciable amount of soluble salts, predominantly sodium chloride, particularly where salt affected soils developed in argillaceous sedimentary rocks, which underlie about two-thirds of the area, and in some granitic rocks. Analysis of 96 samples of unweathered rocks indicate that some contain moderate to appreciable quantities of sodium and chloride, and it is suggested that these and other soluble ions accumulated in the lower zones as a result of deep weathering.

Sharma and Varshney (1979) collected composite soil samples every month during a year and analysed for their pH, available phosphorus, organic matter and moisture contents. They found that amount of available phosphorus in soil profiles were influenced by organic matter, moisture contents and pH of these soils. Available phosphorus content showed positive significant correlation with soil moisture and pH.
Tiwari et al. (1983) reported that salt affected soils of central alluvial region of Uttar Pradesh were suffering badly from alkalinity hazard and showed marked difference in their physico-chemical characteristics. Rahman (1986) showed that the soils are mostly clay in nature. Soils were with bulk densities ranging from 1.24 to 1.35 g cm\(^{-1}\). The EC values were uniform in the soil depths and ranged from 6.1 mmhos cm\(^{-1}\). Sodium is the dominant cation (range: 18.3-55.1 me L\(^{-1}\)) but the concentrations of the Ca\(^{++}\) and Mg\(^{++}\) ions are comparatively lower. Both Cl\(^-\) and SO\(_4\)\(^{-2}\) ions are dominant in the soils. In general, the SAR values were higher in soils and ranged from 5.5 to 19.1. Singh et al. (1987) reported that Na was found the dominant cation, followed by Mg, Ca & K. Cl was found to be the dominant anion followed by SO\(_4\), HCO\(_3\) & CO\(_3\). Exchangeable Na was dominant cation followed by Mg & Ca. Addition of amendment improved the physiological condition and fertility status of the soil.

Sharma et al. (1987) reported that the aridity of the climate, basic parent material and topographical situations resulting in poor drainage were responsible for the formation of contemporary salt affected soils. High clay content and poor hydraulic conductivity were the other factors apart from the genetic factors responsible for secondary salinization in the soils irrigated by canals. More et al. (1988) carried out an extensive survey to characterize the salt affected soils and found that the pH of soils ranged from 8.1 to 10.7 and CEC from 8.0 to 45 cmol (p+) kg\(^{-1}\). Calcium was the dominant cation in saline soils whereas Na was dominant in the sodic soils. ECe were higher in surface layer and decreased down with depth in the profiles. Chlorides and sulphate were dominant in saturation extract of saline and saline-sodic soil profiles whereas bicarbonate content was relatively high in the saturation extract of sodic profile.
Srivastava and Srivastava (1993) studied the influence of soil pH on the transformation and availability of nitrogen in salt affected soils sampled from the Varanasi district of Uttar Pradesh, India. At pH 7.2 and 10.3 the total acid hydrolyzable N contents in the soils were 22.19 and 68.23 %, respectively, whereas the total acid non-hydrolysable N contents were 63.28 and 27.77 %, respectively. The levels of hydrolysable NH$_4$-N, hexosamine-N, serine + threonine N, amino-N, inorganic N (KCl extractable NH$_4$ and NO$_3$), and total N were lower at the higher pH. Humin N and total N accounted for 99 % of the statistical variation between soil N and pH. Organic carbon contents decreased by 0.16 % per pH unit decreasing to 0.20 per cent at pH 10.5.

Szabolcs (1993) reported that salt affected lands account for 10 % of the land surface and can be found in all continents. The only common feature of all salt-affected soils are their high electrolyte concentration. Salt-affected soils can be divided into three categories: naturally occurring salt-affected soils, man-made salt-affected soil, and potential salt-affected land. Amelioration practices in naturally occurring salt-affected lands are only practical where the salt-affected land can be ameliorated easily or where there are reagions for the introduction of intensive production systems, which can be expected to yield fair returns on the investments in the reclamation. Sharma et al. (1994) studied eight soil series identified in the Valley Son River. The soils are alluvial, light textured, generally deep and neutral to saline. Taxonomically the soils are under the order of Entisols and Inceptisols.

Prakash et al. (1995) found that salt affected soils of Sultanpur district of U.P. were mostly flat with a little area of uneven topography. It is mostly barren having white to dark brown colour. The drainage is moderate to
impeded and the water table fluctuates between 1.8 and 6.2 m. pH of the soil ranged from 8.8 to 10.6, EC from 0.6 to 16.8 dSm$^{-1}$ and ESP from 19.5 to 80.5. The values of all these indicates that the process of alkalization had started at the surface and proceeded in downward direction. Among the six soil profiles studied Sanaha, Kinaura, Badagaon and Mishrauli profiles, exhibited the properties of saline - alkali soils while Mubarakpur and Dhammapur profiles were found to be sodic as is evident from their pHs, EC and ESP values. The value of SAR ranged from 17.3 to 280.0, RSC from 11.6 to 205.0 mmol$^1$ and gypsum requirements from 3.8 to 32.2 mg ha$^{-1}$. The values of all these parameters also decreased with increase of depth. This showed higher salinity/alkalinity in the surface layer. Further more the pHs significantly and positively correlated with ESP and SAR ($r = 0.929$ and 0.796) respectively. The regression equation between them worked out as pHs = 8.475 + 0.026, ESP and pHs = 8.999 + 0.0081, SAR, on the other hand ECe was positively correlated with $\mathrm{CO}_3^{2-} + \mathrm{HCO}_3^{-}$ and $\mathrm{Cl}^{-} + \mathrm{SO}_4^{2-}$ ($r = 0.750$ and 0.445) but it was significantly correlated with $\mathrm{CO}_3^{2-} + \mathrm{HCO}_3^{-}$. Soil Survey Division Staff (1995) grouped soils into five categories of saline soils; non-saline (ECe < 2 dSm$^{-1}$), very slightly saline (ECe 2 - 4 dS m$^{-1}$), slightly saline (ECe 4 - 8 dS m$^{-1}$) moderately saline (ECe 8 -16 dS m$^{-1}$) and strongly saline (ECe > 16 dSm$^{-1}$).

Yang et al. (1995) discussed the salt-affected soils of East Asia and its neighbouring regions. Based on studies of types, features and distribution patterns of salt-affected soils, a salt-affected soil map of East Asia and its neighbouring regions has been compiled. The formation and appearance of salinization, its effect on agriculture and the ecological environment, measures of preventing salinization and the exploitation of salt-affected soils
in these regions. Gomez and Garcia (1998) reported that the amount, type and distribution of minerals transported and deposited in the valley was related to a high potential fertility, evolution degree and soil salinization. A vermiculite new formation process and Mg enrichment in the profiles were responsible for the degradation of some soils in the valley.

Padole et al. (1998) examined seven pedons of salt affected soil for morphological, physical and chemical characteristics. The soils were of clay in texture, imperfectly to poorly draining and highly calcareous. The bulk density ranged from 1.28 to 1.88 Mg M$^{-3}$, and a typically low hydraulic conductivity (HC) of the soil, which ranged from 5.2 to 1.7 m/s might be due to high clay and high Na$^+$ content. There was a significant negative correlation between HC and ESP. ($r = 0.7112$). The soils have low to moderate organic carbon, high cation exchange capacity ($>42.3$ c mol (p+) kg$^{-1}$) and high base saturation (73.65 %). Ca$^{++}$ dominates the exchange complex followed by Mg$^{++}$ and Na$^+$. The pH, electrical conductivity (ECe) and exchangeable sodium percentage (ESP) of the soil ranged between 7.3 to 9.6, 0.90 to 5.74 dS m$^{-1}$ and 2.57 to 33.78, respectively. The pH, ECe and ESP values from pedons 2 and 6 indicate saline sodic soils whereas pedons 3, 4 and 5 indicate sodic soil particularly in the subsurface horizons. Na$^+$ and HCO$_3^-$ were the dominant cation and anion in the saturation extract in most soils studied, respectively. A highly significant positive correlation was obtained between the sodium absorption ratio and ESP ($r = 0.9795$) and between pH and ESP ($r = 0.9309$).

Pannu et al. (2000) reported that generally, there was a decreasing trend of micronutrients like Fe, Mn, Zn with increasing depth of soil profile. Sharma and Totawat (2000) carried out experiments by adopting an image interpretation coupled with field study to characterize and classify the salt
affected soils of district Bhilwara, Rajasthan. The soils of study area were alkaline in nature and pH value ranged between 7.24 and 9.40. Further, it could be inferred that an increase in ESP resulted in corresponding increase in soil pH. In general, soils of the study area were poor to medium in fertility and Ca and Mg were the major contributing exchangeable cations followed by Na.

Sherring et al. (2000) reported that the soil properties (pH, EC and SAR) increased up to 60 cm height above the water table depth and then decreased due to more capillary rise near the sodic water. At the top, the salt contents were found less due to leaching of salts. According to Li-Xiao Gang et al. (2002), soluble salts were dominated by sodium ion resulting to sodic soils. With the increase in salinity and sodicity, aggregate stability decreased and clay dispersion increased significantly, with increase in organic matter content (OM), aggregate stability increased and clay dispersion significantly decreased, which showed that addition of organic matter to salt-affected soils can improve structural characteristics.

A laboratory study was conducted by Lu Dian Qing et al. (2002) to investigate the characteristics of soil salt transport under one-dimensional water ponded infiltration. Some indexes for soil salt distribution were recommended based on the characteristics of the partial drainage in the salt-affected soil. Their relationships with the characteristics of the soil water-salt transport were analysed to provide guidance for effective utilization of the salt-affected land. Mzezewa et al. (2003) reported that all soils of the sodic catena exhibited a high degree of compaction, poor drainage status and restricted permeability and contained varying amounts of calcium carbonates (0.1-6.1 %). A marked increase in clay content was noted in profiles of the
mid to upper catena compared to those in lower catenal positions. Soil pH ranged between 7.5 and 10.1. Phenomenal increase in exchangeable sodium percentage (ESP) ranging from 36.9 to 98.9 was recorded in the subsoil horizons of the profiles in upper catenal positions. There was a slight drop in ESP values in soils of the lower catena. Final infiltration rates of 0.01 cm/min were recorded in representative sodic profiles compared to 0.33 cm/min in the control profile. Electrical conductivity values of all soils of the catena were less than 4.0 dS m⁻¹. Bulk densities of the sodic soils were generally high (> 1600 kg m⁻³).

2.2 Effect of salinity and sodicity on plants

Dang et al. (1998) reported that cultivars showed variability in sodicity resistance. Cane yield, sugar yield and commercial cane sugar percentage (CCS %) were reduced by 9-26 %, 12-29 % and 3-5 %, respectively. Exchangeable sodium percentage (ESP) ranged from 14.4 to 23.5 in the cultivars. These reductions were more in early-, than in mid- and late-maturing cultivars. Early-maturing cultivars grown in sodic soil showed Ca deficiency symptoms on younger leaves. Average relative reductions in N, P, K, Ca, Mg, Zn, Fe, Mn and Cu concentrations in the index leaves of these cultivars were 11 %, 19 %, 10 %, 33 %, 6 %, 15 %, 14 %, 14 % and 11 %, respectively, while there was a more than 3-fold increase in Na concentrations. Cultivars having Ca concentration 0.21% in the index leaves exhibited Ca deficiency symptoms. A significant positive relationship between relative cane or sugar yield and relative Ca concentration in sodic versus normal soil indicated the importance of Ca nutrition in sugarcane grown on sodic soil. The Na: Ca ratio in the index leaves of sugarcane in sodic soil was significantly but negatively correlated with relative cane and
sugar yields. Cultivar COJ 64 was the most susceptible, having the highest Na and lowest Ca concentrations in leaves, whereas Cv. CoH 70 the most sodicity resistant and had maximum Ca concentration in leaves under sodic soil conditions. It is concluded that high Ca concentrations and low Na:Ca ratios in the index leaves under sodic conditions may be used by sugarcane breeders to select lines suited to sodic soils. Sharma and Yadav (1988) revealed that increasing levels of ESP increases the concentration of Fe and Mn in soil but reduced their uptake by rice and wheat plants. Growing of rice in sodic soil was beneficial as it improved the availability of Fe and Mn to the subsequent crop of wheat. Rajpur and Wright (1999) reported that the increasing sodicity of soil decreased the survival of plant, shoot height, straw dry weight, and grain yield.

According to Wright and Rajper (2000) sodicity had no effect on the concentrations of Cu$^{2+}$, Fe$^{2+}$, Mn$^{2+}$ and Zn$^{2+}$ in grains and straw, but total uptake of these micronutrients was deceased due to lower dry weight of these tissues per plant. These results suggest that at ESP up to 40-50 adverse physical characteristics are the major cause of low wheat yield in sodic soils, either due to their direct effects in decreasing growth, or their indirect effects in increasing uptake of Na$^+$ and decreasing uptake of K$^+$. Above ESP 50, roots are less able to exclude Na$^+$, even in the presence of improved soil physical conditions, so that at these sodicity levels, both adverse physical and adverse chemical properties contribute to the decreased yield.

Khan and Zaibunnisa (2003) found that viability of pollens was reduced in all the cultivars under salinity-sodicity stress showing significant effect in the salt sensitive Basmati cultivars. The starch synthase activity (1-4 glucan-glucosyle transferases, EC 2.4.1.21) was inhibited more significantly in sensitive than in tolerant cultivars of rice.
2.3. Amelioration of saline and alkali soils

Singh and Pathak (1968) reported that application of ferrous sulphate to alkali soil increased absorption of Mn by oat plant. Mn uptake by plants depressed Fe uptake and vice-versa. Jain et al. (1977) found that the exchangeable K does not appear any systematic variability between calcium and magnesium are less in alkali soil. Copper is found in alkali soil to a range of 0.14 - 0.28 ppm. Singh et al. (1991) reported that the phosphorus adsorption by salt affected soils increased with increasing concentration of phosphate in soil solution. Decrease in percent of added P adsorbed increased the equilibrium P concentration. Maximum adsorption showed significant relationship with EC, ESP and clay.

Bellakki and Badanur (1997) reported that in situ incorporation of sunhemp reduced the bulk density as compared with fertilizer application. Application of sunhemp in combination with fertilizers improved the infiltration rate, water stable aggregates, porosity, field capacity and maximum water holding capacity under drylands. Continuous application of organics increased the CEC and exchangeable calcium while a decrease in Na and CaCO₃ was observed. Available nitrogen, phosphorus, potassium and micronutrients increased significantly with organic sources of nutrients either alone or in combination with fertilizers over the fertilizer alone.

According to Bellakki et al. (1998), a long term field experiment for 10 years on Typical Chromustertts indicated that application of various organic materials to meet 50 per cent N along with 50 per cent NPK recorded significantly lower bulk density. Rice straw incorporation either to meet 50 per cent or 25 per cent N along with fertilizers increased the hydraulic conductivity, water stable aggregates, porosity, soil water retention
characteristics and maximum water holding capacity. Exchangeable Na and CaCO₃ contents decreased but there was increase in CEC and exchangeable Ca content of the soil due to incorporation of different organic sources of nutrients. Available major and micronutrients increased significantly with combined application of organic and inorganic sources of nutrients.

According to Al Sharif et al. (1998) the physical and chemical soil properties were improved by using gypsum, especially, pore size distribution, bulk density, structure, soil salinity and alkalinity. Soil salinity was reduced markedly where the ECe values decreased from 29.25 to 10.1, 7.15, 3.5 and 2.7 dSm⁻¹ for treatments of leaching technique using canal water, drainage water, gypsum + canal water and gypsum + drainage water, respectively.

Abdul et al. (1998) conducted a laboratory study to determine the effect of adding farmyard manure (FYM), Egyptian clover hay (*Trifolium alexandrinum*), and wheat straw at 1 and 3 % of soil weight on water stability of soil aggregates (WSA), water-holding capacity (WHC), pH, and electrical conductivity of soil extract (ECe) of a normal, saline, and saline sodic soil. After 90 and 180 days, WSA and WHC increased, while pH and ECe decreased. Soil properties improved most by adding 3 % manure to all the soils. Kumar and Kumar (1998) conducted trials on sodic soils, *Dalbergia sissoo, Azadirachta indica, Acacia nilotica* and *Leucaena leucocephala* were planted 4 m x 2 m apart in the monsoon season of 1993 along with *Setaria sphaelata, Chloris gayana, Brachiaria mutica* and a trispecific hybrid between the rows. The best performing species were *Dalbergia sissoo* and *Setaria sphaelata*. There was a substantial improvement in soil physicochemical properties.
Singh *et al.* (1998) reported that reclaiming salt affected soils for tolerant crops may be easy, requiring less time and low costs. On the other hand reclaiming such lands to suit sensitive crops will need much longer time and higher investments. Abdul-Ghafoor (1999) reported that lower Ca\(^{2+}\) in irrigation water to be better for soil amelioration than its higher concentration.

Rajpur and Wright (1999) reported that treatment of sodic soil with an anionic polyacrylamide soil conditioner resulted in large increases in the proportion of water stable aggregates, and increased survival, increased shoot height, and increased grain yield. At the highest ESP tested, grain yield per plant decreased by 76%, but in the polymer-treated soil the decrease was only 12%. Treatment of the sodic soil with the polymer increased K\(^+\) and K\(^+\): Na\(^+\) ratio, but decreased Na\(^+\) in flag leaf sap. The effects of the polymer on Ca\(^{2+}\) and Mg\(^{2+}\) were relatively small. Hence in this experiment, when the structure of sodic soil was stabilized, the decreases in growth and yield of wheat, even at high sodicity levels, were relatively small. The results suggest that the primary cause of low wheat yield in sodic soils is poor soil structure and that the decrease in yield due to high ESP is relatively small.

Gritsenko and Gritsenko (1999) reported that new forage crops (*Malva crispa*, *M. meluca*, *Sida* sp., *Helianthus divaricatus*, *Helianthus tuberosus*, and others) may be used for desalinization of secondary saline irrigated soils and for raising their fertility. Bauder and Brock (2001) conducted a study with Haverson silty clay (fine-loamy, mixed, calcareous, mesic Ustic Torrifluvent) to determine the effect of combinations of chemical amendments, crop species, and irrigation water quality on Na\(^+\) and salt leaching from salt-affected soils. Amendments included CaSO\(_4\), P-
CaSO₄ and MgCl₂ and a unamended control treatment. Crops included alfalfa (*Medicago sativa* L.), barley (*Hordeum vulgare* L.), sorghum-sudangrass [(*Sorghum vulgare* x *Sorghum drumondii*) (sordan)], and a noncropped control. Irrigation with high SAR high TDS water increased the soil solution EC to approximately 5.5 dS m⁻¹, but did not decrease crop yields relative to irrigation water having SAR and TDS of 0.37 and 747 mg kg⁻¹, respectively. Magnesium displaced Na⁺ on the exchange complex, but the effects were short-term as compared to CaSO₄ or P-CaSO₄. Amendments increased yields of barley from 14 % - 27 % and alfalfa by 25 % but had no effect on sudan.

According to Niu-Ling An *et al.* (2001) increasing time of soil amelioration and improving fertilizer application, the quantity and quality of soil organic matter in the salt-affected soil improved steadily from the first to the second generation, and the third generation of experimental area successively, as demonstrated by an increase in total humus, humic acid / fulvic acid (HA: FA) ratio and content of functional group, and an decrease in E465:E665 (visible light absorption value) rate.

Sneh-Goyal *et al.* (2001) found that plantation and growing of intercrops could be an effective way of ameliorating such soils. In a 7-year field trial on a moderately saline-alkali soil of Hisar, Haryana, India, plantation of Melia azedarach (*Azadirachta indica*) with intercrops of green manure (*Sesbania aculeata*), mustard, wheat and barley led to improvement of soil with respect to pH and electrical conductivity (EC). The soil organic carbon (OC) and total N were more in crops with tree plantation. Similar trends were also observed for soil microbial biomass carbon (MBC), soil respiration and soil enzyme activities.
According to Quadir et al. (2001) phytoremediation against soil application of gypsum and farm manure and water treatment with sulfuric acid on a calcareous saline-sodic soil (pHs = 8.0-8.4, ECe = 24-32 dS m\(^{-1}\), SAR = 57-78, CaCO\(_3\) = 45-50 g kg\(^{-1}\) for the top 0.15 m depth; Calcic Haplosalids). A saline-sodic water (EC = 2.9-3.4 dS m\(^{-1}\), SAR=12.0-19.4, RSC=4.6-10.0 mmolc l\(^{-1}\), SAR adj =15.6-18.4) was used to irrigate the rice (*Oryza sativa*) and wheat (*Triticum aestivum*) crops grown in rotation. Active desalinization and desodification processes were observed in all the treatments. After the final wheat crop, the 1.2 m soil profile ECe was 7 ± 0.5 dS m\(^{-1}\) and SAR was 15 ± 2 with non-significant treatment differences, indicating comparable soil amelioration effect of phytoremediation with other treatments. Better crop yields were obtained from the manure-treated plots, owing to its annual addition to the soil that possibly improved soil fertility.

Ram et al. (2000) reported that use of 30 or 60 kg N from organic sources in a total application of 120 kg N increased grain and straw yields, N uptake and recovery, grain nutritive value, decreased soil pH and increased soil fertility and economic returns. Use of 50 % organic fertilizers in the total application was recommended.

Mishra et al. (2002) reported the ameliorative effect of *Dalbergia sissoo*, planted on sodic land at district Sultanpur, Uttar Pradesh, India, in a tropical environment, was studied at 3, 6 and 9 years of age. The soil properties of the sites improved significantly, showing marked reduction in pH, electrical conductivity (EC) and exchangeable sodium percentage (ESP) and an increase in organic carbon, nitrogen and availability of nutrients in the soil. The significant reduction in Na\(^+\) was found in all the age groups. Results showed an improvement in the soil moisture regime due to increased
infiltration rate (cm hr\(^{-1}\)), soil permeability (cm\(^2\)), water-holding capacity, field capacity and pore space whereas, the bulk density decreased significantly after successive years of planting. The effect on soil attributes was confined to surface soil in the young plantation and deeper in older plantation.

According to Kumar and Singh (2003) there was a slight reduction in soil pH while electrical conductivity (EC) of the soil decreased significantly with the application of fly ash as measured after paddy and wheat crops. The sodium adsorption ratio of the soil decreased with increasing fly ash levels, while gypsum treatments considerably added to its favourable effects. Fly ash application increased the available elemental status of N, K, Ca, Mg, S, Fe, Mn, B, Mo, Al, Pb, Ni, Co, but decreased Na, P and Zn in the soil. An application of fly ash to the soil also increased the concentrations of above elements except Na, P and Zn in the seeds and straw of paddy and wheat crops. The results indicated that for reclaiming sodic soils of the south-west Punjab, gypsum could possibly be substituted up to 40 per cent of the gypsum requirement with 3.0 per cent acidic fly ash.

2.4. Studies related to aromatic crops:

Ng (1972) found economic yields of lemon and citronella grasses (*Cymbopogon spp.*) and vetiver grass (*Vetiveria zizanioides*) obtained from fertilizer trials were found to be comparable with those reported elsewhere. Lemon grass and citronella grass grown on podzolic soil produced average fresh weight yields of 11.47 tons/acre and 9.87 tons/acre, respectively, in the first year. These gave oil yields of approximately 75 lb for lemon grass and 133 lb for citronella grass. The mean oil content was 0.40% v/w and the yield about 21 lb/acre. Of the three aromatic grasses lemon grass (*C.
citratus) grown on peat makes the greatest profit and citronella grass (C. nardus) the least (which is mainly attributable to the low price of its oil at the present time). Present yield results seem to show promise for their exploitation on a commercial scale. Nair et al. (1979) conducted an experiment with lemongrass and observed that the herbage and oil yields were increased significantly due to the application of Zn. Agrawal and Gupta (1982) observed that the application of pyrites resulted in increased dry matter, grain yield and oil content over control.

Singh and Anwar (1985) observed that palmarosa, lemongrass and citronella can be grown in salt affected soil without significantly reduction in herb and oil yield up to an EC of 11.5, 10.0 and 5.5 mmhos cm\(^{-1}\), respectively. At 7.5 mmhos cm\(^{-1}\) EC while the herb yield of citronella was reduced by 32 to 54 % over control (0.5 mmhos cm\(^{-1}\)), that of palmarosa increased by 12 to 16 % with the effect bearing of lesser magnitude on lemongrass. Even at EC level of 11.5 mmhos cm\(^{-1}\), palmarosa yield suffered by 3 to 6 % only as against more than 80 % in case of citronella. Oil content and its quality with respect to geranial in palmarosa and citral in lemongrass were not affected by increasing levels of salinity upto 15 mmhos cm\(^{-1}\).

Rao et al. (1987) examined 20 aromatic plant species, growing on P deficient soil had VAM fungi in their root systems. Root colonization was highest in Mentha piperata and Mentha spicata, but was not correlated with chlamydospore counts in the rhizosphere soil, highest in Artemisia pallens. Anwar et al. (1988) conducted a green house experiment on the salt tolerance of vinca rosea (Catharanthus roseus L.), Egyptian herbane (Hyoscyamus mutinus L.) and rye (Secale cereale) for ergot on soils of graded salinity revealed that yields of vinca rosea and Egyptian henbane herb were significantly decreased at a salinity of EC 12 dS m\(^{-1}\). The ergot
yield from rye was not reduced up to EC16 dS m\(^{-1}\). The reduction in the yield of vinca rosea leaves and roots and egyptian henbane at EC 12 dS m\(^{-1}\) over control was of the order of 61.3, 51.9 and 40.8 per cent, respectively.

Ghosh (1989) conducted the agro-technology studies of essential oil yield and reported that plant species clearly revealed the possibility of commercial cultivation of *Cymbopogon* spp. The three species of *Cymbopogon* (*C. flexuosus*, *C. martinii* and *C. winterianus*) *C. flexuosus* (OD-19) crop proved to be promising showing better growth, oil yield and oil quality and crop may be commercially exploited in this area (hooghly, W.B.) for upliftment of rural economy.

Shahi and Sen (1989) revealed that leaf analysis for *C. jwarancusa* plants at 3 sites showed significant variations in essential oil content. The soil moisture content was responsible for up to 92 % in the variation in essential oil content. Thomas *et al.* (1990) observed that the crop produced tallest plants in the winter (I\(^{\text{st}}\) harvest) due to flowering and highest biomass and essential oil yields in the rainy season (III\(^{\text{rd}}\) harvest) due to favourable weather conditions. Lowest yields were recorded in summer (II\(^{\text{nd}}\) harvest) due to shorter plants and fewer numbers of tillers per plant, but the essential oil content was more in summer season (0.70-0.83 % as against 0.60-0.68 %) in rainy season.

Chattopadhyay *et al.* (1991) reported the elemental composition and nutrient uptake of aromatic plants. Subrahmanyam *et al.* (1991) reported that growth and oil yield of *Japanese mint* was significantly increased by the direct and residual effect of Fe. Pal *et al.* (1992) reported that the increasing level of SAR enhanced the sodium content and decreased N, P, K, Ca and Mg content on plants. Singh and Singh (1992) reported that fresh herbage and essential oil yields were significantly influenced by application of N.
upto 200 kg N ha$^{-1}$ yr$^{-1}$, while in tissues N concentration and N uptake increased only to 150 kg N ha$^{-1}$. The oil yields with neem cake coated urea and urea super granules were 22 and 9 % higher over that with prilled urea and urea super granules were significantly increased upto 200 kg N ha$^{-1}$, while with neem cake coated urea, response was observed only to 150 kg N ha$^{-1}$.

Kothari (1996) observed the effects of different row spacing (45, 60 or 75 cm) and application of varying amounts of N fertilizer (0, 100, 200 or 300 kg N ha$^{-1}$) on growth and essential oil production and composition of Japanese mint ($M$entha arvensis) cv. HY-77 were studied in field experiments on a sandy loam soil at Lucknow. Maximum oil yield (232 kg ha$^{-1}$) was recorded for the combination 75-cm row spacing and 300 kg N ha$^{-1}$. Closer row spacing of 45 cm produced taller plants but was found to be inferior to the wider row spacing of 60 or 75 cm due to shedding of leaves from the middle and lower parts of the canopy, particularly at a high N rate. To obtain the maximum benefit it is suggested that the crop is planted at 60-cm row spacing and supplied with 240 kg N ha$^{-1}$.

Rao and Chand (1996) reported that plant height, number of tillers per plant, biomass and essential oil yield of lemon grass increased significantly with the application of Zn, while essential oil concentration and chemical composition (geraniol 0.3-1.0 % and citral 87.1-89.3 %) were not affected significantly. At the level of 10 kg Zn ha$^{-1}$, the total (sum of three harvest) biomass and essential oil yields increased by 98.1 % and 121.5 %, respectively. Singh et al. (1996) observed the growth response of Japanese mint to NH$_4^+$-N fertilizer application under alkaline soil conditions resulted from absorption and utilization of NH$_4^+$ and other elements, including trace elements, and a decrease in pH in the rhizosphere leading to increased
availability of NH$_4^+$-N on account of a reduction in volatilization. Singh et al. (1996) investigated the pattern of accumulation of important monoterpenes in the essential oil of *C. winterianus* leaves in 4 cropping seasons (April to June, June to August, August to October and October to January) during one year's crop growth. Maximum essential oil accumulation was recorded at a crop age of 69 days during the summer (April to June) when the crop experienced the highest air temperature and lowest relative humidity. However, the lowest air temperature and moderate relative humidity experienced by the crop during winter (October to January) provided good conditions for citronella oil quality, which was best at a crop age of 63 days. Singh et al. (1996) in his study concluded that the growth response of Japanese mint to combined NH$_4^+$ + NO$_3^-$ fertilizer application resulted from exhaustive utilization of both NH$_4^+$ and NO$_3^-$ nitrogen and improvement in the uptake and utilization of macro and micronutrients.

Yadava et al., (1996). Planted lemongrass at 3 spacings (30 x 45, 45 x 45 and 60 x 60 cm) and NPK fertilizers were applied at 4 rates (0:0:0, 150:60:40, 200:80:60 and 250:100:80). The combination of the 45 x 45 cm spacing and the highest fertilizer rate proved to be superior with regard to the number of tillers (78 and 114), plant height (153 and 156 cm), herbage yield (57.6 and 68 t ha$^{-1}$) and oil yield (260.9 and 309.4 kg ha$^{-1}$) when compared with the other treatments in the first and second years, respectively, and also produced the highest net returns (Rs. 60 237 and Rs. 100 555 in 1993 and 1994, respectively). The oil content and quality was similar in all the treatments.

Chattopadhyay et al. (1997) reported that citronella Java (*Cymbopogon winterianus*), suffering from iron chlorosis, received foliar
application of iron solutions containing different chelates of iron, both natural and synthetic organic substances. The 6 treatments consisted of ferrous sulphate alone or combined with EDTA, citric acid, lemon juice, tartaric acid or tamarind extract. Foliar applications of iron chelates were more effective than inorganic ferrous sulfate; natural organic substances like lemon juice could be utilized as effective iron carriers in place of EDTA or analogous compounds.

Chauhan et al. (1997) examined the performance of aromatic crops such as lemongrass (*Cymbopogon flexuosus*), citronella Java (*Cymbopogon winterianus*), palmarosa (*Cymbopogon martinii*) and Japanese mint (*Mentha arvensis*) in Eucalyptus hybrid (*E. tereticornis*) plantations and reported that Eucalyptus growth, in terms of height and diameter, was improved by the intercrops. Amongst the intercrops, herb and oil yields were lowest for lemongrass, while oil yield was highest for citronella Java and intermediate in palmarosa. Herb and oil yields of lemongrass did not decrease with increase in the age of the trees, while oil yield in citronella and palmarosa decreased with increasing tree age after the third year when compared with the sole crop. Lemongrass performance was judged to be the best with respect to sustained herb and oil productivity during the entire growth period. Net annual returns recorded over the 5 years were Rs. 22,800 ha-1 from the Eucalyptus monoculture, and Rs. 41,338 from the lemongrass, Rs.38,898 from the palmarosa, Rs.37,179 from the citronella and Rs.35,403 from the Japanese mint-based cropping systems.

Khaliq and Janardhanan (1997) observed significant variation in effectiveness of different VAM fungi on mints. Inoculation of VAM fungi did not affect the herb essential oil content or composition in any of the mints examined. VAM inoculation, in general, improved the shoot biomass
production of all the species. The results suggest the potential use of VAM fungi for improving the productivity of commercially cultivated mints.

Muniramappa et al. (1997) reported that the application of 100 kg N ha\(^{-1}\) have tallest plants (34 cm), and greatest plant spread (646 cm\(^2\)), number of branches (21), number of leaves (36) leaf area (116 cm\(^2\)), fresh and dry weight per plant (15.3 g and 9 g) and per ha (3.01 t and 1.3 t). However, it was at a par with 75 kg N ha\(^{-1}\) for most of the yield characters. Application of phosphorus at 75 kg ha\(^{-1}\) resulted in the tallest plants (32 cm), and greatest plant spread (553 cm\(^2\)), number of branches (20) and leaves (35), fresh and dry weight per plant (12 g and 7 g), herbage per hectare (2.79 t and 1.17 t) and andrographolide content (3.58 %).

Patra et al. (1997) revealed that palmarosa was the most tolerant and lemon grass the least tolerant of the sodic environment. On an average 2 -9 % reduction in palmarosa essential oil yield and a 11-20 % reduction in lemon grass essential oil yield were observed in sodic soils compared with normal soils. Soil sodicity had no significant influence on herb and essential oil yield of palmarosa. Essential oil quality of all tested species was not significantly influenced by sodicity. Prasad et al. (1997) observed the root cation exchange capacity (CEC) determined by the exchange reaction with Ca) decreased in the order: Mentha arvensis > Mentha citrata [Mentha piperita var. citrata] > Mentha spicata > Mentha piperita > Mentha cardiaca [Mentha gracilis]. Cultivar differences in the root CEC of M. arvensis and M. spicata were also observed. The concentrations of N, K, Na and total cations (Ca + Mg + K + Na) in the shoots were not significantly correlated with root CEC. However, root CEC was significantly and positively correlated with the concentrations of Ca, Mg and the ratio of divalent to monovalent cations in the shoots.
Kumar et al. (1999) carried out pot experiments to evaluate the performance of palmarosa and vetiver and their ameliorative potential for improvement of sodic soil. Five sodicity levels [(ESP 16 control) 55, 65, 75 and 85] were developed by using NaHCO₃. Results indicated that oil yield of palmarosa significantly increased at ESP 55 (14.93 %) over control but further increases in ESP levels to 65, 75 and 85 decreased the oil yield 36.10, 59.70 and 73.37 %, respectively over the oil yield obtained at ESP 55. In case of vetiver oil yield increased up to ESP 65 (16.44 %) as compared to control and decreased at ESP 75 and 85 by 14.12 and 27.06 %, respectively in comparison to oil yield of ESP 65. Palmarosa crop reduced the soil ESP by 2-20 units and vetiver 3-27 units during experimental period.

Ram et al. (1999) reported that chamomile could successfully be grown on soils having an ESP up to 53 without any prior reclamation. Growth parameters such as plant height, plant spread and number of branches, dry weight of shoots and flower yield decreased with increasing sodicity but increased with increasing fertility. Growth parameters and flower yield increased significantly up to 60 kg N ha⁻¹. The highest flower yield (10.1 and 13.5 g plant⁻¹ in 1995 and 1996, respectively), was obtained with the combined application of 120 kg N, 50 kg P₂O₅ and 50 kg K₂O ha⁻¹.

Singh (1999) reported that number of tillers per plant and fresh herbage yield of palmarosa significantly increased with the application of Zn (10 kg Zn ha⁻1). At this level, the total fresh herbage increased by 32.5 %. The essential oil content was the highest in third harvest (0.61-0.67% as against 0.43-0.51 % in other harvests). Rajput et al. (2000) observed that the biomass and essential oil yields of mentha mint increased significantly over respective control treatments with soil applications of 10 kg, 4 kg Cu, 15 or 30 kg Fe, 10 kg Mn, 2 kg B and 0.1 kg Mo ha⁻¹. The percentage increase
ranged from 16.0 – 44.9 % and the maximum increases were recorded with B and Mo applications. The highest biomass (16.8 and 17.6 t ha⁻¹ in 1999 and 2000) and essential oil (115.2 and 117.8 kg ha⁻¹ in 1999 and 2000) yields were obtained with 2 kg ha⁻¹ boron addition. Singh et al. (2000) reported that the grasses have good soil binding capacity which helps to control soil erosion and improve coal mine overburden dump stability.

Prasasd et al. (2001) studied interactive effect of irrigation water salinity and soil fertility on the salinity and sodicity build-up in soils, yield and cation composition of palmarosa and lemongrass. The herb and oil yield of palmarosa significantly decreased at high salinity (ECiw 18.8 d S m⁻¹) while that of lemon grass consistently decreased with increase in salinity. Increasing soil fertility increased the herb and oil yield of palmarosa but had no effect on lemongrass. The concentration of Na in shoot tissue of palmarosa and lemongrass increased with increase in salinity. Palmarosa had lower concentration of Na higher capacity to maintain their K and Ca concentrations in the shoot tissues at high salinity than lemongrass. A high accumulation of Na and low concentration of K and Ca in shoot tissues was in accordance with the drastic herbs yield reduction in lemongrass under increased salinity stress.

Singh et al. (2002) found that palmarosa without any amendment gave normal yield on the salt affected soil and improved physicochemical characteristics of the soil. The crop with pyrites or pyrites plus other amendments like sludge and hyacinth compost had better effect than the crop alone on the improvement of saline sodic soil under study. The pH, ECe, ESP and SAR of the soil decreased whereas hydraulic conductivity increased. Content of organic carbon, available N, P, K, Cu, Zn and Fe
increased. Maximum improvement was recorded with palmarosa crop on plots treated with 3 t hyacinth compost + 2 ton sludge + pyrites @ 40 % of gypsum requirement ha⁻¹. The amendments used were not only able to increase herb yield but were also able to escalate essential oil yield of the palmarosa. Therefore, it is inferred that palmarosa grass can profitably be grown on saline sodic soils. It may play role of a dual purpose crop by improving salt affected soil on the one hand and giving normal yield on the other hand.

2.5. Water Quality and their effects on Soil Characteristics and Crop

Classification of irrigation water

Significant contribution have been made to our knowledge of water quality by Hilgard (1906); Kelley et al. (1940); Kelley and Brown (1928); Scofield (1936); Scofield and Headley (1921); Scofield and Wilcox (1931); Eaton (1935, 1950); Doneen (1954); Thorne and Thorne (1951); Wilcox (1948, 1955) and U.S. Salinity Laboratory staff (1954).

In classification of irrigation water, it is assumed that the water will be used under average condition with respect to soil texture, infiltration rate, drainage, quality of water used, climate and salt tolerance of the crop. Large deviation from the average for one or more of these factors may make it unsafe to use water that would be safe under average conditions. Similarly under some unusual circumstances it may be possible to use water that would be considered unsafe under average conditions. Although the proposed methods of classifying irrigation waters differ somewhat, they agree reasonably well with respect to criteria and limits.

The U.S. Salinity Laboratory (1954) proposed a number of characteristics that determine water quality. In general, the recognized
criteria of irrigation water quality are (i) salinity hazard (ii) sodium hazard and (iii) specific effect of certain toxic constituents like B, HCO₃, Cl, Na, Li etc. The classification of irrigation waters proposed is based upon the conductivity (salinity) and SAR (sodium) values. The four salinity and four sodium hazard classes are discussed below:

(i) **Salinity classes**

Under this class waters are divided into four groups with respect to conductivity, between classes being at 0.25, 0.75, and 2.25 dS m⁻¹. These class limits were selected in accordance with the relationship between electrical conductivity of saturation extracts.

(ii) **Sodium classes**

There are four sodium classes of low, medium, high and very high waters; their division is dependent both on their SAR and total salt concentration in a way that waters with a constant SAR value are given higher sodium hazard rating with an increase in their salinity.

(iii) **Effect of B concentration on water quality**

According to U.S. Salinity Laboratory B may be toxic to the sensitive crops when the irrigation water contains more than 1 ppm. Scofield (1936) proposed the limits for B toxicity shown as following:

<table>
<thead>
<tr>
<th>Boron classes</th>
<th>Sensitive Crops (ppm)</th>
<th>Semi tolerant Crops (ppm)</th>
<th>Tolerant Crops (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0.33</td>
<td>0.67</td>
<td>1.00</td>
</tr>
<tr>
<td>2.</td>
<td>0.33 to 0.67</td>
<td>0.67 to 1.33</td>
<td>1.00 to 2.00</td>
</tr>
<tr>
<td>3.</td>
<td>0.67 to 1.00</td>
<td>1.33 to 2.00</td>
<td>2.00 to 3.00</td>
</tr>
<tr>
<td>4.</td>
<td>1.00 to 1.25</td>
<td>2.00 to 2.50</td>
<td>3.00 to 3.75</td>
</tr>
<tr>
<td>5.</td>
<td>1.25</td>
<td>2.50</td>
<td>3.75</td>
</tr>
</tbody>
</table>
Plant species differ markedly in their tolerance to high concentration of boron.

(iv) Effect of bicarbonate on irrigation water quality

Carbonate waters are strongly alkaline, but bicarbonate waters are only mildly. So, in waters containing high concentration of these ions, there is a tendency for calcium and possibly magnesium to precipitate as carbonates when water is concentrated by transpiration. Due to precipitation of Ca and Mg the relative proportion of Na is increased with an increase in alkali hazard. The residual sodium carbonate (RSC) proposed by Eaton (1950) is defined as:

\[
RSC = (\text{CO}_3^- + \text{HCO}_3^-) - (\text{Ca}^{++} + \text{Mg}^{++})
\]

In which the concentrations are expressed in me L\(^{-1}\). Waters with RSC greater than 2.50 me L\(^{-1}\) were considered unsuitable for irrigation, those with RSC 1.25 – 2.50 me L\(^{-1}\) were regarded as marginal and waters with RSC value less than 1.25 me L\(^{-1}\) were considered safe.

(v) Toxicity of other ions

Eaton (1950) used the term soluble sodium percentage (SSP) to decide water with quality and a value higher than 60 was considered unsafe. It is likely that both the Na\(^+\) and Cl\(^-\) ions may not accumulate to any significant degree in the soil as pointed out by Kelley (1951); yet citrus trees are injured if the irrigation waters are high in these constituents. When water with high sodium percentage is continuously applied, the deteriorative effect on the physical conditions of the soil is not marked till the irrigation is replaced by waters of lower electrolyte concentration.
SSP = Na\(^+\) x 100/ Ca\(^{++}\) + Mg\(^{++}\) + Na\(^+\)

Little information is available on the alkali tolerance of crops. The following classification gives the tolerance of crops to different levels of exchangeable sodium percentage (Brahson, 1960):

<table>
<thead>
<tr>
<th>Class</th>
<th>ESP</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very sensitive</td>
<td>2 – 10</td>
<td>Deciduous fruits, nuts, citrus and avocado</td>
</tr>
<tr>
<td>Sensitive</td>
<td>10 – 20</td>
<td>Beans</td>
</tr>
<tr>
<td>Moderately</td>
<td>20 – 40</td>
<td>Clover, oats, tall fescue, rice and dallies grass</td>
</tr>
<tr>
<td>Tolerant</td>
<td>40-60</td>
<td>Wheat, cotton, alfalfa, barley, Tomato and beets</td>
</tr>
<tr>
<td>Very tolerant</td>
<td>60</td>
<td>Crest and fairway wheat grass, Rhodes and tall wheat grass</td>
</tr>
</tbody>
</table>

Raychaudhery and Shankarnarayan (1952) found in India that saline soils mostly occur with a high water tables with in critical limits to cause salinization. According to Agrawal et al. (1956) the well water of Etah, Farrukhabad and Kanpur distirct present on immature soils were found to contain very high amount of salts able to cause salinity problem if used normally on local soil. Lewis and Juve (1956) reported significant correlation between SAR of the irrigation water. The amount of calcium carbonate of soil showed increase when irrigation water contained high Ca\(^{++}\) and HCO\(_3\)\(^-\) ions. According to Agarwal et al. (1957) introduction of canal irrigation is also a cause for soil salinity.
Darra et al. (1964) reported that the waters of wells are from moderately to very highly alkaline and canal waters are of good quality. In general the waters of Rajasthan can be classified as saline alkaline.

Szaboies (1964) reported that interaction of $\text{Na}_2\text{CO}_3$ containing irrigation water with soil increase alkalinity and Na adsorption. Mehta et al. (1968) reported that the quality of well waters has been found to deteriorate in most of the cases. The change in quality was not found to be influenced by rising trend of underground waters, nearness to canal and soil characteristics.

Mehrotra (1969) reported the effect of naturally occurring brackish water, in some specific areas on tobacco crop. It was observed that the crop was receiving as much as 1100 kg of nitrogen per hectare through irrigation from this water. It was also found that it was possible to simulate this composition artificially and the water thus synthesized gave yields nearly approaching those from natural waters. Chaudhari and Khepar (1970) found that salt accumulation depended on texture, water table depth and salt concentration of ground water in their study on Punjab soils.

Mishra and Gajendra Gadker (1970) reported that the main reason for the development of salinity and alkalinity in the Chambal command area are (i) use of alkaline water for irrigation, (ii) rise of water in the areas where canal irrigation has been introduced and (iii) slow permeability of soils.

Kanwar and Mehta (1970) reported the mean B content in surface of irrigated soils in the Sangrur district of Punjab and Hissar district of Haryana, in the range of 0.36 to 1.38 ppm, associated with irrigation water containing mean B content of 0.09 to 0.99 ppm. Jain and Saxena (1970) reported that high sodium in irrigation water has caused sodiumization of the
soil and in a few cases sodium has accumulated at lower depth. Boron content is comparatively lower in irrigation water and is present in higher amount in the soil. Boron and sodium has increased simultaneously in the soils.

Singh and Sharma (1970) examined the effect of high RSC water on the physical and chemical properties of irrigated soils in the semi arid zone of Rajasthan. Irrigation with waters containing increasing concentration of residual sodium carbonate affected the properties of the irrigated soil to the increasing degree of deterioration, whereas good to fairly good yields were obtained with water of RSE 2.9 and 6.8 me L⁻¹. Poor yields were obtained with RSC 11.2 me L⁻¹ water.

Paliwal and Maliwal (1971) found that irrigation waters of various quality have shown that electrical conductivity and contents of calcium, magnesium, sodium and potassium in the irrigation waters are significantly correlated with those of the saturation extract of soils. Sharma and Abrol (1973) evaluated the quality of some important drain water in Haryana. They found that the water of Karnal district drains has electrical conductivity of < 1000 micromhos cm⁻¹ except TRI - 1 sodium the dominant cation and most of the water contain RSC but their amount is generally less than 2.5 me L⁻¹. Conversely, Rohtak district drain waters dominate in chloride and are characterized by absence of RSC except TRI-4 and Nohra drains which come from Karnal. The quality of these water is within safe limits and can easily be utilized for irrigation purposes.

Singh (1973) reported that in Agra district of U.P., 47 samples of ground water contained on an average 0.72 ppm B. The associated irrigated and unirrigated soils contained 0.81 and 0.87 ppm B (Water soluble), respectively. Thus accumulation of B in soil was not appreciable more than
that of the irrigation waters. However, water soluble B was positively correlated with pH, EC, SAR, Cl, SO₄, and B of the irrigated soils.

Verma (1973) reported that continuous irrigation with highly saline ground waters (EC 15 mmhos cm⁻¹) containing B in concentration of 3.5 ppm for oven 15 years did not cause accumulation of B in the irrigated soil. Bingham et al. (1974) reported that uniform application of irrigation water varying in salinity and sodicity hazards. Water quality representing low to moderately high salinity and also with Cl⁻ and SO₄²⁻ water resulted in soil salinity profiles specific for each water. The quantity and quality of oranges have declined under irrigation treatment producing accumulation of soluble salts with in the root zone.

Lal and Singh (1974) reported that hydraulic conductivity decreased with an increase in SAR of the irrigation water, while it increased with increasing salt concentration. An increase in clay resulted in reduced hydraulic conductivity. Sharma and Lal (1975) reported that the hydraulic conductivity of sandy soil decreased from 9.12 to 8.32 cm hr⁻¹ and of clay loam (medium black soil) decreased from 1.18 to 1.05 cm hr⁻¹, under irrigation with waters having SAR values of 21. However, with the increases of salinity of irrigation water (EC 2.6 to 6.3 mmhos cm⁻¹), the hydraulic conductivity of soil increased from 4.51 to 4.87 cm hr⁻¹.

Gupta (1978) observed that when irrigation water containing 10 ppm B was equilibrated with sand and medium black soil, only 2 ppm was adsorbed in sand, whereas 8 ppm was adsorbed in medium black soil. Since adsorbed B did not affect the plant growth, relevance of these findings is that relatively high B water could be used on heavy textured soils as compared to light textured ones.

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Saha and Acharya (1978) reported that increasing electrolyte concentration of the irrigation water increased the soil water diffusivity, more so with increasing water content and ESP of the soils. The weighed mean diffusivity increased by 2.8, 3.1, 20, 40 and 164 times for soils of ESP 5, 14, 22, 30 and 70, respectively when the electrolyte concentration of percolating water was increased from 0 to 40 me L\(^{-1}\).

Singh and Pal (1978) worked and analysed irrigation waters and corresponding irrigated soils at different altitudes showed that total soluble salts of irrigation waters and soils, SAR of water and ESP of soil were decreased by the dilution effect of monsoon rains. The cationic and anionic composition of the waters generally remained unchangeable. Salts accumulated during rabi through the use of saline waters of low SAR were almost completely washed down by rain water, while the saline irrigation waters associated with high SAR increased the ESP of soil, which affected the salt balance and salt regime coefficient markedly.

Pal and Poonia (1979) found that the RSC of water decreased from 5.75 to 0.75 me L\(^{-1}\) after passing water through the gypsum bed, CO\(_3^-\) + HCO\(_3^-\) concentration remained unchanged, showing no precipitation of CaCO\(_3\) in the gypsum bed. Jain (1981) reported that frequent irrigations with saline water were conducive for higher values of ET (Evapotranspiration) and LF (Leaching Fraction) and to lower the salinity and ESP levels of the soil, thereby resulting in higher yields of different crops. You and Wang, (1983) observed the soil and hydrogeological conditions of the salt-affected soil regions and found that there are three patterns of well application for the improvement of salt-affected soils: (1) a combination of well irrigation and well drainage in regions where the groundwater is fresh or contains only small amounts of minerals; (2) a
combination of deep and shallow wells in regions that have mineralized groundwater; and (3) shallow well drainage in regions of highly mineralized groundwater.

Manchandra et al. (1985) reported that sodic water of fixed sodium adsorption ratio (SAR) 16 and total soluble salts (25 me L\(^{-1}\)), but increasing RSC levels were used in wheat-bajra rotation on a sandy loam soil in Lysimeters, for three years. Bajra fodder yield decreased consistently with rise in the RSC of water and was reduced to 50% at a soil ESP of 15 and pH of 9.0.

Sharma and Manchanda (1989) showed that wheat, bajra (Pennisetum americanum) and guar (Cymopsis tetragonaloba) crops could be grown successfully even if sodic water is used for irrigation in area of southern Haryana, provided gypsum was added @ 100% GR of the soil plus required to neutralize RSC\(_{iw}\) completely on cumulative basis, before the onset of monsoon. They found that the grain yield increased with the increase in the RSC content of irrigation water but was less than the yields obtained with a control treatment of canal of the irrigation water but was less than the yields obtained with a control treatment of canal which neither saline or sodic. Even through soil pH in the crop root zone and plant sodium was maximum in the 10 RSC and minimum in the zero RSC treatment, still grain yield was greater in the 10 RSC and least in the zero RSC treatment. Significantly less accumulation of chlorides in plants in the 10 RSC relative to lower RSC treatment was associated with higher grain yield. The results suggest that chickpea is more susceptible to the presence of sodium chloride than sodium bicarbonate salts in the root zones and its irrigation with HCO\(_3\) dominated sodic waters is not as harmful as its irrigation with Cl\(^-\) dominated sodic water equal EC and Na contents.
Chauhan et al. (1990) examined multiple correlations between water quality parameters and soil characteristics and observed that salinity build up in soil is positively correlated with salinity of water while pH was influenced by EC$_w$ and RSC and SAR$_w$ and RSC below and above 18 SAR of water, respectively. Degree of dispersion in both the groups of water had significant positive correlation with SAR$_w$ and RSC and negative with EC$_w$ whereas hydraulic conductivity had the reverse relationship with corresponding water quality parameters.

Khandelwal and Lal (1991) conducted a pot experiment on the same soil for two years with four types of soil (loamy sand, sandy loam, sandy clay loam and clay loam) with different qualities of irrigation water to study their effect on soil properties, grain and straw yield of wheat. EC$_e$ of soil increased with an increase in EC of irrigation water. ESP and pH of the soils increased with an increase in SAR of irrigation water. Boron content of soil increased with an increase in clay percentage of the soil. Grain and straw yields decreased with an increase in EC and SAR of irrigation water, but the effect was less on permeable light textured soils. Grain and straw yields increased with low boron in irrigation water, but decreased at higher level. The effect was less on clay soil than on light textured soil.

Tiwari et al. (1991) monitored the physico-chemical and biological parameters of the river Alaknanda. Water quality was assessed by comparison with existing standards for important parameters. Dissolved oxygen showed positive relationships with temperature. Turbidity, total alkalinity, hardness, free carbon dioxide, chloride concentration, total dissolved solids, zooplanktons and phytoplanktons showed marked variations during monsoon and winter seasons.
Islam (1993) studied fresh river and saline drainage water with total dissolved solids (TDS) 7.200-7.318 g L\(^{-1}\) were continuously supplied to the surface of the soil monoliths from an automatic water supply container, maintaining a constant water head of 10 cm over the surface of the monoliths during the period of leaching (irrigation). Salt contents and exchangeable cations in soil were determined before and after leaching. Results showed that exchangeable calcium increased and exchangeable magnesium, sodium and total exchangeable cations decreased in the soil due to the effect of river water used for irrigation. Exchangeable calcium and magnesium increased more markedly and exchangeable sodium and total exchangeable cations decreased more sharply in the soil, resulting in increased infiltration, porosity and hydraulic conductivity of soil due to the effect of the saline drainage water.

Astarael and Chauhan (1994) studied the effect of irrigation waters varying in Mg/Ca, salinity and SAR on wheat in micro plots. The grain yield in first year decreased significantly at 4 Mg/Ca ratio with 6 dS m\(^{-1}\) salinity of water while it was so at 6 with 12 dSm\(^{-1}\). But Mg/Ca ratio of 4 significantly decreased grain at both the levels of SAR (10 and 50 mmole L\(^{-1/2}\)). In second year critical level of Mg/Ca ratio shifted to 8 irrespective of salinity and SAR of water. Irrespective of Mg/Ca ratio N, P, Na and Mg contents in plant increased and Ca, Mg and K decreased and those of Na and N increased. Increasing Mg/Ca ratio increased Na, Mg, N and decreased Ca and K contents in plants at higher salinity and SAR of irrigation water.

Girdhar (1995) found that the build up of salinity increased with depth of soil at a given level of the EC of the irrigation water. This shows that application of low saline water to sorghum and wheat crop in saline soil helped in leaching the salt to lower depth soil salinity also increased with an
increase in SAR at high salinity of the water. The effect of salinity water on change in soil pH in different years was non-significant in sorghum wheat rotation.

Suvarna and ACharya (1995) studied the decomposition of aquatic plants *Hydrilla verticillata, Pistia stratiotes,* and *Azolla spp.* in Indian water resources in relation to the subsequent impact on water quality. After 10 days incubation, 10.7, 16.6 and 9.5 % dry weight losses were recorded, respectively. After 40 days incubation very little mass was left to degrade, whilst the concentration of carbonates in the water increased and oxygen was completely removed. There was little change in pH compared to the control.

Badraoui *et al.* (1996) reported for centre pivot units having the same soil type, salinization increased as a function of increased irrigation water salinity and the number of years under irrigation. Sodification of the soil increased with the increase of irrigation water sodium adsorption ratio only in clayey soils. No relationship was found between ESP and permeability. The number of years necessary to reach critical EC values for cereal crops varied from one pivot unit to another. Singh and Singh (1997) reported that the higher RSC in irrigation water significantly decreased the herb and oil production of lemon grass (*Cymbopogon cytratus*) and increased the pH and EC of the sandy loam soil. However, increases in EC were observed only in surface (0-15) soil.

Chhibba *et al.* (1998) reported that increasing sodicity of irrigation water and the increasing frequency of treating the soil with the water of a particular residual sodium carbonate caused a decline in the DTPA-extractable micronutrient cations, more prominently in Zn followed by Mn. The magnitude of this decline was relatively greater in the sandy loam than...
that in the loamy sand soil and it showed a significant negative correlation
with exchangeable sodium percentage of soil.

Kim et al. (1998) showed that the water quality was better than the
criteria for irrigation water and the concentrations of chemical oxygen
demand and NH₄-N of the Kwangju stream, contaminated with sewage
water, were 9.7 and 3.61 mg L⁻¹, respectively. In July and August, it had
better water quality than any other investigated month due to dilution with
rainwater. Singh et al. (1998) reported that increasing use of poor quality
water for irrigation and the continuous addition of waste salts to the
environment, along with increasing contamination of underground water
sources, are worsening the already alarming situation.

Feizi et al. (1998) observed that the effects of irrigation with water
quality of 2, 5 and 8 dS m⁻¹ on the ECe and ESP of the soil on wheat and
sugar beet crops, with four replications, over 5 years. The results showed
that as irrigation water salinity (ECi) increased, the soil salinity (ECe) and
exchangeable sodium percentage (ESP) also increased. The ECc of 0-60 cm
soil depth was 6.9 after 5 dS m⁻¹ years irrigation with ECi =1.8 dS m⁻¹
water. The ECe for water 4.9 and 8.2 dS m⁻¹ was 8.2 and 10.6 dS m⁻¹
respectively. ESP reached 21, 24 and 33.5, respectively. Dragovic et al.
(1998) reported that salinity build-up occurs in several small water recourses
that pass through heavy clay soil areas with high salinity and shallow water-
table. Furthermore there is some pollution by urban and industrial waste
waters. Increased salt concentrations were found in the systems located on
heavy soil types, with ECw of 3 dS m⁻¹ or more. High increases were also
found in SAR and chloride and sulphate contents. Calculated correlation
coefficients show that the observed changes are highly significant.
Dragovic et al. (1998) reported that although the quality of water for three main rivers of northern Yugoslavia is satisfactory, urban and field drainage effluents entering into small water-resources have highly significant salinity effects on local irrigation schemes that reuse this water. High increases have been detected in ECw and SAR and chlorides and sulfate contents. Multiple correlations and regressions were used to show that irrigation with salt-affected water has increased ECe, SAR, chloride and sulfate contents.

Bishnoi et al. (1998) carried out a detailed survey of underground irrigation waters of 61 villages of in Ludhiana, Punjab, India and collected 484 samples. All the samples (except one) contained total salts within the permissible limit for irrigation. Soluble sodium varied from 0.21 to 11.4 me L⁻¹ with a mean value of 4.67. On the basis of residual sodium carbonate (RSC), 50, 31 and 19 % of samples were graded in fit, marginal and unfit categories, respectively. Soluble carbonates and bicarbonates in these waters varied from nil to 5.60 and 1.2 to 14.0 me L⁻¹ with mean values of 1.52 and 5.87, respectively. Potassium content varied from 0.08 to 2.08 me L⁻¹ with an average value of 0.24. Considering the mean value, each hectare meter of water is capable of supplying 94 kg of K to crops. The sulphate content varied from 0.02 to 2.96 me L⁻¹ with an average value of 0.67, 79 % of the samples contained < 1 me L⁻¹ of sulphate.

Chhibba et al. (1998) reported that the increasing RSC in irrigation waters caused a general decrease in the contents of available Zn, Cu, Fe and Mn in the soil. The effect of increasing RSC on available Cu and Mn content was more pronounced only in fields receiving irrigation with waters having RSC >5.0 me L⁻¹.
Xiao et al. (1998) reported that the higher the mineralization of irrigation water, the greater the soil hydraulic conductivity because a high sodium-adsorption ratio (SAR) of irrigation water would have an unfavourable effect on soil hydraulic conductivity. Irrigation water with a very low mineralization had an irreversible effect on soil hydraulic conductivity, inducing a significant decrease of soil hydraulic conductivity.

Das (1998) collected water samples from various sources of Canning (I and II blocks, respectively) West Bengal, India, during 1991-94 and classified on the basis of electrical conductivity (EC) and sodium adsorption ratio (SAR). There was an increase in salinity and Na⁺, Mg²⁺, Ca²⁺, Cl⁻ and B concentrations of irrigation waters, with the change in the time of collection from December-January to April-May. Water of each class strongly influenced the salinity of the irrigated soils except class I water having EC 1.0 dS m⁻¹ and SAR <10 (m mol L⁻¹)¹/². Using the threshold salt concentration limit of 1 to 1.3 mg L⁻¹ (EC 1.5-2.3 dS m⁻¹) of water and its influences on corresponding soils, 77 and 47 % of water in Canning I and II blocks, respectively, were suitable for irrigation during December-January and 35 and 25 % during April-May.

Morais et al. (1998) analysed 1077 samples and evaluated. The evaluation showed that 36.59 % water were of categories C₁S₁, C₂S₁ and C₂S₂, which were considered of good quality. 52.73 % were classified as C₃S₁, C₃S₂, C₄S₁ and C₄S₂, which can be used for irrigation depending on the type of soil and crop. 10.68 % belong to classes C₃S₃, C₃S₄, C₂S₃, C₂S₄, C₄S₃ and C₄S₄. Only 5.66 % caused infiltration and 60 % present crescent risk of toxicity due to chlorine and sodium. With respect to pH, 84.40% have values considered normal and only 0.84 % presented potential problems due to bicarbonate. It was also verified that 20.98 and 0.56 % of the waters
presented high degree of restriction to use, when evaluated through electrical conductivity Na, Cl, and HCO₃ values taken isolatedly and jointly, respectively.

According to Costa (1999), infiltration of rainfall caused a substantial dilution of salt concentration. Changes in sodicity were persistent, but tended to stabilize between SARₑ = 5 to SARₑ = 7. When irrigation was discontinued for a year and 1129 mm of rainfall leached the soil, the SARₑ value decreased from 5.3 to 1.8. Kₛ showed a threshold at exchangeable sodium percentage of 5.

Gritsenko and Gritsenko (1999) reported that irrigation with mineralized water results in the salinization and solonetz-formation of soils and in a decrease in their fertility status. Filep (1999) reported that the chemical parameters used to express the quality of irrigation water were reviewed and correlations were calculated between the three basic parameters (the salt concentration, Na⁺ percentage and SAR value of the water) using the limit values recommended by Hungarian water classification guidelines and in the international literature. Using equations calculated, natural water sources with various compositions were divided into precisely defined and easily interpreted quality classes. The role of (HCO₃⁻ + CO₃⁻⁻) in increasing the alkalinity of the water, which thus modifies the classification given, can be estimated from Na percentage, SAR values corrected with the effective Ca²⁺ concentration, which depends on the HCO₃/Ca ratio, or with the effective (Ca + Mg) concentration.

Quddus and Zaman (1999) selected 24 villages and investigated the physico-chemical properties of irrigation water and classify them according to their suitability for irrigation purposes. Analysis were done for pH, electrical conductivity, total dissolved solids, NO₃⁻ N, P, K, Ca, Mg, Na, B,
SO$_4^{2-}$, S, Zn, Fe, Cu, Mn, CO$_3^{2-}$, HCO$_3^{-}$ and Cl. Sodium adsorption ratio (SAR), potassium adsorption ratio (PAR), residual sodium carbonate (RSC), and soluble sodium percentage (SSP) were calculated from the data generated from chemical analysis. Non significant variation was obtained between the surface and groundwater but in most cases B and S concentrations were higher in groundwater than in surface water. The pH indicated the alkalinity of irrigation water. SAR and EC values showed that the sample were medium saline and low alkaline. Boron and Fe contents were within safe limit but water sampled from Singhati, Kathalpota, Kutubpur and Fetapur villages had comparatively higher amount of B (0.77-0.98 mg L$^{-1}$). The rest of the elements did not pose any threat on the quality of water and can safely be used for irrigation in Meherpur.

Quist and Williams (1999) found that the tree species varied in their responses to the saline irrigation treatments. Some showed increases and others decrease in the contents of a specific nutrient element. Further, although the impact of low quality water was evident, none of the elements tested were in the deficient or toxic range. Nayak et al. (2000) studied the pattern of water retention and transmission in relation to sand, silt, and clay, ECe, CEC and ESP in saline black soil. The saturated hydraulic conductivity had significant positive correlation with sand and EC and significant negative correlation with clay, ECe, CEC and ESP. The results also indicated that clay in the soil is a major contribution factor to the variations in saturated hydraulic conductivity the extent of 52.33 %. ECe of the soils accounted 89.36 and 72.04 % variation to the water retention at FC and AWC respectively, whereas CEC accounted 86.61 % variation to the water retention at WP. Four variable viz. clay, CEC, ECe and ESP combinely accounted highest percent of variation to saturated hydraulic
conductivity. While the single factor clay alone contributed 52.33 % variation to the prediction equation of Ks.

Endo et al. (2000) reported that irrigation water quantities should be supplied in amounts and qualities just enough to meet crop requirements without extracting salt accumulation. Singh et al. (2000) collected one hundred and sixteen soil samples (58 each from irrigated and unirrigated soils) and 58 irrigation water samples were collected from 58 sites of semi-arid region (Jhunjhunu) of Rajasthan and analysed for electrical conductivity and pH. The water samples were further analysed for soluble cations and anions and SAR, adjusted SAR, RSC and pH were also calculated. From salinity and alkalinity index of irrigated and unirrigated soils, it was observed that soils were within the permissible limit of salinity and sodicity. However, irrigated soils showed slightly higher EC and pH than unirrigated due to continuous irrigation with saline-sodic water. Inspite of this process, the secondary salinization was not so high. This was mainly due to light textured soils of the tract. The effect of poor quality irrigation water on soil salinity and alkalinity was evident from the regression analysis. The EC of irrigation water had significant positive correlation \( r = 0.885 \) with EC of irrigated soils. The pH of irrigated soil had significant positive correlation with RSC \( r = 0.472 \) and SAR \( r = 0.529 \) of irrigation water.

Somasundaram et al. (2000) examined the effect of dried lopping of amla tree \( (Phyllanthus emblica) \) on the improvement of irrigation water quality, irrigation water from three different sources (bore well and 2 open wells), with varying water quality, and distilled water (control) were treated with dried lopping at four concentration levels \( (0, 5, 10 \text{ and } 15 \%) \). Treatment with amla tree dried lopping at varying concentration invariably decreased the pH and slightly increased the electrical conductivity of
different irrigation waters. In the high RSC water used, treatment with amla at 5% level decreased the pH from 9.1 to 7.1 within a day after treatment and stabilized to 6.5, but EC increased from 1.8 to 1.98 and stabilized to 2.14 after a week. In all the treatments, Na and K concentrations increased leading to slight increase in electrical conductivity. The treatments of alkali (high RSC) water with amla tree dried lopping improved the quality of irrigation.

Khan (2001) analysed the of groundwater samples collected from wells situated at different distances from the river bank (zone A river water - 0 -100 m from the river), zone B (0-100 m), zone C (101-250 m), zone D (251-500 m) and zone E (501-1000 m from the river) revealed that the area closest to the river is most affected. The effluent discharged to the river is the main source of ground water contamination. Concentration of sodium and chloride was higher with a proportional increase in total dissolved solids and electrical conductivity (EC) values in the well water within the zones. There is a decreasing trend in ion concentration from zone A to zone E and F, reflecting the reduced effect of effluents. The pollution of water resources has resulted in the degradation of other natural resources such as land, soil and vegetation. Nearly 4463 hm² (20.38 %) of the area under study has been very severely affected. The EC value at different sites exceeds 20 d S m⁻¹ soil and lands have become hard, compact and saline. Cropping intensity has declined. Over the 3633 hm² of the area classified as severely affected, the EC value of water varies from 10-20 dS m⁻¹. Irrigation with such water has created problem of salinity and sodicity in soils. Herbal biomass declined considerably. Double cropping has almost stopped. Almost 8494 hm² area is affected moderately. EC of groundwater varies from 5 to 10 dS m⁻¹ fragile surface crust, declining levels of phosphorus and potassium...
in the soil, poor density of natural vegetation are significant effects. A further area of 5305 hm\(^2\) area is slightly affected.

According to Bauder and Brock (2001), due to prolonged irrigation with water of marginal quality, salination of irrigated soils in some areas of southeastern Montana has led to a need for better understanding of the soil and water management alternatives for irrigators. Brar et al. (2001) reported that the electrical conductivity (EC) of the water samples varied from 720 to 4200 micro mhos cm\(^{-1}\), which was significantly related with residual sodium carbonate (RSC) and CO\(_3\) and HCO\(_3\). The values of CO\(_3\)\(^-\), HCO\(_3\)\(^-\) and RSC varied from 0.2 to 4, 2.0 to 4.5 and -10.1 to 15.8 Me L\(^{-1}\), respectively. SAR varied from 0.68 to 17.25 and was positively correlated with RSC (r = 0.56) and EC (r = 0.22).

Al-Nabulsi (2001) conducted an experiment in split plot design with three irrigation water qualities (normal water, drainage water and a 1:1 mixture of freshwater and drainage water) as the main treatments, two irrigation frequencies (at 7 and 14 - day intervals) as the sub treatments and two crops (barley Cv. Gusto and lucerne Cv. Higazi) as the sub-sub treatments. The soil infiltration rate was highest in the barley plot receiving freshwater irrigation at weekly intervals. The lowest soil infiltration rate was found in lucerne plots receiving saline irrigation water at 14-day intervals. Bulk density and proportions of micropores (pore radius, r < 1.4 \(\mu\)m) were higher and the proportion of macropores (r > 14.4 \(\mu\)m) was lower in barley than in lucerne. Saline irrigation caused the greatest decrease in total porosity.

Sarkar (2002) reported that treatment of gypsum to ponds exhibited increasing trends in the concentration of N, P, exchangeable Ca and soil pH. The mean concentration of bottom fauna species dominated by (*Chironomus*
larvae, *Odonata nymph*, *Tubifex* and *Planorbis*) increased from 7.5-26.8 g/m² with the addition of gypsum. Gypsum increased fish yield from 210-660 kg ha⁻¹ per 6-month. Results of Slavich *et al.* (2002) showed that all groundwater treatments caused the soil to increase in salinity from ECₑ (0-0.15 m) 0.6-0.9 dS m⁻¹ to 3.8-7.3 dS m⁻¹ and sodicity from SAᴿₑ (0-0.15 m) 1.7-2.1 to 14.2-16.8 after 2 years of application.

Results of Pateras *et al.* (2002) showed that the irrigation waters, both surface and groundwater, possess a potential risk for land degradation. The suspected sea water intrusion to the groundwater reservoirs alarmed the need for measures to be taken. Such measures concern a very limited use of the groundwater and the storage of good quality water into the reservoirs through a separate filling up channel network.

According to Perez *et al.* (2003) salinisation and occasionally, alkalinisation increased with increasing salt concentrations of the water used. The study of the water-soluble ions present in the soils allows determining the main factors influencing these processes. A statistical study proves that changes in the salinity of the waters used for irrigation, agricultural practices, the use of fertilizers, and salts supplied by runoff of the surrounding areas are the essential factors that have led the soils to their actual condition. Tomar and Minhas (2004) carried out a field experiment with relative performance of aromatic grasses citronella (*Citronella java*), lemon grass (*Cymbopogon citrates*), palmarosa (*Cymbopogon martini*), and vetiver (*Vetiveria zizanioi*) under saline water irrigated condition. They reported that maximum suitability of vetiver followed palmarosa and lemongrass but citronella could not survive. The reductions in yield with saline irrigation were varied from 24-29 %.
Tomar and Minhas (2004) conducted an experiment related to performance of medicinal plant under saline water irrigated condition at Hissar. Selected some medicinal plant like Isabgol (*Plantago ovata*), Aloe (*Aloe barbadensis*), Kalmeg (*Andrographis paniculata*), Periwinkle (*Catharanthus roseus*), Ocimum (*Ocimum sanctum*) and Mint (*Mentha piperita*). Isabgole was proved to be most suitable under saline water irrigation and Periwinkle has showed poor performance with saline irrigation.