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Full Length Research

Utilization of Sewage Effluents for Irrigating Crop Plants I – Percentage Seed Germination and Seed Germination Index in Certain Crop Plants

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The present study included physico-chemical analysis of Sewage Effluents (SE) entering the River Yamuna at Mathura UP India with effect of SE water on certain crops of the region to assess its potential utilization for irrigating crop plants for increasing improved and sustainable agricultural production. As such SE was analyzed and its effect in various concentrations (25%, 50%, 75% and 100% along with Controls as distilled water) on seed germination was performed on four crops wheat, barley, mustard and broad bean. Mustard and Broad bean did not show any seed germination at all in the SE treatment concentrations at 24 hours duration. Besides, in Broad bean no germination was observed at 48 hours too in all the SE treatments. Further, it was observed that 75% SE treatment and also 72 hours of germination were found to be quite critical for all the crops. The results in relation to the effect of different concentrations of SE exposure on germination performance measured in terms of Germination Percentage (GP) and Speed of Germination Index (SGI) have shown germination performance as C3 Mustard>C4 Broad bean>C1 Wheat>C2 Barley at critical duration and critical level of 72 hours in 75% SE concentration showing better performance of Mustard and Broad bean than Wheat and Barley.

Key words: Sewage Effluent, Germination Percentage (GP), Speed of Germination Index (SGI), crop varieties.

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INTRODUCTION

The steady increase in industrialization, urbanization and enormous population growth are leading to production of huge quantities of wastewaters that may frequently cause environmental hazards. Paucity of quality fresh water for agriculture has made wastewater application a popular option. This makes wastewater treatment and wastewater reduction very important issues (Khurana and Singh, 2012; Snehlata, 2016). The present study offers a collection of studies and findings concerning wastewater treatment, minimization and reuse. Water supply and water quality degradation are global concerns that had intensified with increasing water demand; for this reason, worldwide marginal-quality water has become an increasingly important component of agricultural water supplies particularly in water scarce regions. The status of severe water resources shortage determines that new water source must be developed to cope with the deficiency of water sources for agriculture irrigation. One of the major types of marginal-quality water is the wastewater from urban and peri-urban areas (Pedrero et al., 2010). The municipal wastewater is a potential water resource with stability of water quantity and reliable supply. Irrigation with reclaimed municipal wastewater that is properly treated and satisfied with the agricultural recycling standards has huge benefits and profound social effects (Shi et al., 2008). In recent years wastewater use has gained importance in water-scarce regions. In Pakistan 26% of national vegetable production is irrigated with wastewater (Ensink et al., 2004). In Ghana, informal irrigation involving diluted wastewater from rivers and streams occurs on an estimated 11,500 hectares, an area larger than the reported extent of formal irrigation in the country (Keraita et al., 2014). In Mexico about 260,000 hectares are irrigated with wastewater, mostly untreated (Mexico CAN, 2004). In India, estimates revealed that ~73,000 hectares were irrigated with wastewater during early nineties and presently the area under wastewater irrigation is on the rise (Strauss and Blumenthal, 1990; Astera, 2014). Wastewater reuse in agriculture is an ancient practice that has been generally implemented worldwide. Agricultural deployment of wastewater for irrigation is based on the value of its constituents, which are used as fertilizers. However, crop irrigation with insufficiently treated wastewater may result in health risks. The use of sewage effluent for irrigation exposes the public to the dangers of infection with a variety of pathogens such as bacteria, viruses, protozoa and helminths. Thus, the benefit of wastewater reuse is limited by its potential health hazards associated with the transmission of pathogenic organisms from the irrigated soil to crops, to grazing animals and humans (Gupta et al., 2009). Human health risks from wastewater irrigation include firstly farmers' and consumers' exposure to pathogens including helminth infections, and secondly, organic and inorganic trace elements. Protective measures such as wearing boots and gloves, and changing irrigation methods can reduce farmer exposure (Qadir et al., 2010).

Further, ground water resources in most areas of world are shrinking at an alarming rate and may not meet the ever increasing demands from agriculture and industry in future. However, increasing the productivity of water and making safe use of poor quality waters in agriculture will play a vital role in easing competition for scarce water resources, prevention of environmental degradation and provision of food security (Parashar, 2011; Parashar and Sharma, 2017). Driven by the pressure to produce more, even the effluent rich saline and alkali waters are being increasingly diverted to irrigated agriculture (Sharma, 1982; 1987; 2015; 2017; Nauhbar, 2005; Rani, 2007; Gautam, 2009; Rani et al., 2009). There are two major approaches to improving and sustaining productivity in a poor quality water irrigation environment: modifying the environment to suit the plant and modifying the plant to suit the environment, but the former has been tried more extensively. The available options are mediated through the management of crops/sequences, irrigation water, chemical/amendments and other cultural practices but all must be integrated as per the site specific needs and achieving higher yields on sustainable basis. Some important interventions include appropriate crop/variety selection, blending effluents and fresh water to keep the resultant effluent toxicity below threshold, or their cyclic application by scheduling irrigation with salty water at less salt sensitive stages. At the farm/irrigation system level, policy measures like re-allocation of water to higher value crops and those with limited irrigation requirement, spatial re-allocation and transfer of water, adopting policies that favor development of water markets and adequate utilization of groundwater can help in improving water productivity in polluted environments. The other viable options include effluent irrigation tolerant agro-forestry systems and bio-effluent agriculture. Besides technological advances, peoples' participation and favorable water use and allocation policies need to be put in place for sustainable use of effluent waters (Sharma, 1976; Sharma, 2004; Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017).

Sewage is the water-borne waste derived from domestic waste and animal or food processing plants consisting of human excreta and other organic wastes from kitchen and bathrooms, paper, cloth, soap, detergents etc. Raw sewage consists of about 99.9% of water and about 0.1% of solids. Seventy percent of these are organic constituents and 30% are inorganic. Sixty percent of the organic substances are proteins, while carbohydrates and fats represent 25% and 19% respectively. The inorganic fraction constitutes grit, salts and metals in varying proportions (Tebbutt, 1977). The irrigation of grasslands and crop-fields with sewage is an ancient practice followed in Prussia for more than 450 years beginning 1559. Raw sewage has been flood irrigated in pastures at Melbourne, Australia since 1897. Mahida (1981) sites several examples where sewage has been used for irrigation. But, with the increasing urbanization and industrialization, the disposal of sewage effluents is becoming a serious problem all over the world. The composition of sewage sludge changes with the type of industries discharging their effluents into the sewer system. This material can be considered as an organic manure and soil amendment. The addition of sewage sludge to agricultural land has been reported to increase the yields of many crops (Sharma, 2004; Unnamalai et al., 2007; Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017). Besides, many countries face periodical drought periods and a continuous deficit of good-quality fresh water resources due to severe water pollution problems. Most countries will face it within 20-25 years. Therefore, agriculture must use alternative water resources for increasing crop production for the ever growing population to feed. The basic idea is to achieve good yield of uncontaminated agricultural products as well as cash crops so as to make agriculture sustainable (Annan, 2005).

Mathura, a semi-arid region, faces water scarcity throughout the year with ground water being highly brackish and not fit for irrigation. Yamuna River and wells are the main sources of water in Mathura. There is pressing demand for supplemental water to augment crop production. Therefore, in Mathura use of sewage effluents after treatment and proper dilution with normal water making them suitable for irrigation is the most favorable approach. It serves as an additional potential source of fertilizer for agricultural use and also prevents the wastewater from being an environmental hazard in minimizing pollution load of the water-bodies (Gautam, 2009; Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017). The reuse of wastewater for agricultural purposes is becoming more necessary as good quality water becomes scarce. Further, the proper use of this wastewater for irrigation has a two-fold advantage; it conserves a valuable resource and takes advantage of nutrients present in sewage effluents for crop requirements. Since the nutrient status and inferior quality of water bring major constraints in the development of agriculture, harvesting the nutrient energy of biological/organic and industrial wastewater is of prime importance for maximizing the food, feed, and fodder and fuel production (Khurana and Singh, 2012). Thus, the wastewater can be used to irrigate the fields in rural areas and maintenance of large playgrounds, parks, nurseries and green belts in the urban areas. Besides, the wastewater irrigation may solve various associated problems of its disposal and may give a new life to the rivers, natural streams and other water-bodies and soils receiving this wastewater in which the pollution load can be minimized to a large extent (Sharma, 1976; Sharma, 2004; Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017). Besides, the ground water quality in Mathura region is highly saline and brackish. The rainfall is inadequate and unevenly distributed. The canal water from the lower Agra canal distribution system does not reach the remote fields of the cultivators in the villages (Gautam, 2009). There is, therefore, a pressing demand for supplemental irrigation water to augment crop production (Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017; Parashar et al., 2018). Thus, the present study is an effort and aims at a detailed study of potential water quality problems in the light of industrial and urban development in Mathura with an attempt to see its effects on plant growth and development especially agricultural crops of the region so that the quality of water is best utilized for irrigation to raise higher crop yields so as to make sustainable improvement of crops.

MATERIALS AND METHODS

The present study was conducted at the Eco-physiology Laboratory, Department of Post-graduate Studies and Research in Botany, K R College, Mathura (Dr B R Ambedkar University, formerly Agra University, Agra) UP, India during 2014-15 under laboratory conditions.

The present study includes physico-chemical analysis of sewage effluents entering the River Yamuna at Mathura. Effect of sewage on crops with sewage effluent water was observed to assess their potential utilization for irrigating crop plants for increasing improved and sustainable agricultural production. As such sewage effluent was analyzed and its effect in various concentrations (25%, 50%, 75% and 100% along with Controls as distilled water) on seed germination and early seedling growth was performed on four crop plants, wheat, barley, mustard and broad bean.

Physico-chemical Analysis and Characterization of the Sewage Effluents from two Selected sites in Yamuna River at Mathura was carried out following Trivedi and Goel (1986), Manivasakam (2000), Singh et al., (2008), AOAC (2012), Snehlata (2016), Parashar et al., (2018) for water colour, odour, transparency, turbidity, temperature, pH, total alkalinity, free CO_2, DO, BOD, COD, TSS, TDS, Cl^-, Ca^{2+}, Na^+, K^+, Mg^{2+}, SO_4^{2+}, inorganic PO_4^{--}, particulate PO_4^{--}, total dissolved PO_4^{--}, total Kjeldhal PO_4^{--}, NH_3-N and NO_3-N.

The four crop varieties selected for the present study are most commonly grown in western U.P. particularly in Mathura and nearby areas. The seeds of the material involved in the present study were kindly provided by the Agriculture Research Centre Raya, Mathura UP India.

The following crop plants were chosen for experimentation:

1. Wheat (*Triticum aestivum* L. variety P.B.W. 373) family Poaceae
2. Barley (*Hordeum vulgare* L. variety Barley Narendra) family Poaceae
3. Mustard (*Brassica campestris* L. variety Pusa Jaikisan) family Brassicaceae
4. Broad bean (*Vicia faba* L. local variety) family Papilionaceae/Fabaceae

Studies on the Effect of Irrigation with Sewage Effluents on Seedling Growth

Seed lots of the four crop varieties were screened for their relative tolerance to sewage effluents (SE) under varying concentration levels *viz*., 0, 25, 50, 75 & 100 %. Distilled water was used as Control. As such seed germination and seedling growth was carried out on wheat, barley, mustard and broad bean crops of the region by Garrard's Technique (Garrard, 1945), as modified by Sarin and Rao (1956), as per method of Sheoran and Garg (1978), followed by Sharma (1982, 1987, 2015, 2017) and Parashar and Sharma (2017). Seed Germination was measured as Germination Percentage (GP) and Speed of Germination Index (SGI). The speed of germination index (SGI) was determined by following the formula of Carley and Watson (1968): SGI = (5x1G + 4x2G +3x3G + 2x4G + 1x5G) Where, 1G ——— 5G = Number of seeds germinated on the first (24 hours) to fifth (120 hours) day.

Preparation of stock solution

Stock solutions for irrigation with Sewage Effluents (SE) were prepared as follows:

1. 0% Solution Distilled Water (DW) was used as Controls
2. 25% Test solution was prepared with 25% SE + 75% DW
3. 50% Test solution was prepared with 50% SE + 50% DW
4. 75% Test solution was prepared with 75% SE + 25% DW
5. 100% Test solution was prepared with 100% SE

Sterilization of seeds and $HgCl_2$ salt treatment

Three hundred seeds of each variety were surface sterilized by soaking in 0.1% (w/v) $HgCl_2$ for 2 min and then rinsed twice with sterile distilled water. Sterilized seeds were subjected to SE treatment in varying concentrations in petri-dishes for seed germination containing autoclaved sterilized filter paper (Whatman No1) saturated with different concentrations of SE treatment. The petri-dishes were kept in BOD incubator at 25±2^{0}C temperature. Observations of the influence of SE as 25% test solution, 50% test solution, 75% test solution and 100% test solution of SE solutions and the Controls (DW grown) were recorded at 24 hour intervals from 24 hours after sowing up to the end of 120 hours. Seed germination was calculated after 24, 48, 72, 96 and 120 hours. Three replications with 100 seeds were taken for all the experimentation.

Statistical Analysis

All parameters with three replicates were analyzed by 'Analysis of Variance' (ANOVA) by using window SPSS package (SPSS 17.00 version). Data were expressed as the mean ± standard error of the mean. CD at 0.01 and 0.05 percent probability were calculated wherever the results were significant.

RESULTS AND DISCUSSION

Physico-chemical Observations of Sewage Effluents

Physico-chemical Characterization of Sewage Effluents (SE) was done for water colour, odour, transparency, turbidity, temperature, pH, total alkalinity, free CO_2, DO, BOD, COD, TSS, TDS, Cl^-, Ca^{2+}, Na^+, K^+, Mg^{2+}, SO_4^{2+}, inorganic PO_4^{--}, particulate PO_4^{--}, total dissolved PO_4^{--}, total Kjeldhal PO_4^{--}, NH_3-N and NO_3-N. The results of the analysis of Sewage Effluents (SE) at two sites (Site I- Masani Nala and Site II-Sewage Farm) have been shown in the Table 1.

1. **Colour**: The water sample showed a Black colour at Site I while Yellowish colour at Site II.

2. **Odour**: It was found to be Foul-pungent smell at Site I and Stinking-pungent smell at Site II.

3. **Transparency**: Water transparency also differed at the two sites with Blackish at Site I and 4. Yellowish at Site II.

4. **Turbidity**: Coming to water turbidity with higher value at Site I (14.0 ± 0.0 NTU) and lower at Site II (8.5 ± 0.07 NTU).

5. **Temperature**: Site I (26.66 ± 1.0 ^{0}C) and Site II (32.33 ± 1.54^{0}C).

6. **Hydrogen Ion Concentration**: Hydrogen ion concentration i.e., pH showed lower values at Site I (acidic 6.66 ± 0.09) whereas at Site II the pH was observed to be (alkaline 7.5 ± 0.1).

7. **Conductivity**: Conductivity was found to be very high with lower (630.0 ± 2.46 dsm^{-1}) at Site I and higher (840.0 ± 0.12 dsm^{-1}) at Site II.

8. **Free Carbon Dioxide**: Free Carbon dioxide showed the lower value at Site I (170.0 ± 0.0 mg/l) and highest values were recorded at Site II (220.0 ± 1.12 mg/l).

9. **Dissolved Oxygen**: Observations of Dissolved oxygen (DO) levels showed lower values at Site I (45.0 ± 1.0 mg/l) with an upward trend at Sites II (76.33 ± 0.78 mg/l).

10. **Biological Oxygen Demand**: Biological Oxygen Demand (BOD) levels also showed very high values with lower at Site I (188.33 ± 0.78 mg/l) with an upward trend at Site II (200.0 ± 1.75 mg/l).

11. **Chemical Oxygen Demand**: Chemical Oxygen Demand (COD) values were also observed to be high enough ranging from lower values at Site I (370.0 ± 1.0 mg/l) followed with upward values at Sites II (396.33 ± 0.66 mg/l).

12. **Total Suspended Solids**: Total Suspended Solids (TSS) with lower values at Site I (1032.66 ± 2.33 mg/l) and the higher at the Site II (1312.0 ± 2.08 mg/l).

13. **Total Dissolved Solids**: Total Dissolved Solids (TDS) content was lower at Site I (1902.33 ± 2.4 mg/l) and higher at Site II (2071.33 ± 2.4 mg/l).

14. **Chloride Ions**: Regarding the Anion (-ve ions) Chloride ions (Cl^-) the variation was quite observable with lower being at Site I (620.66 ± 1.0 mg/l) followed upwardly at the Sites II (660.33 ± 1.75 mg/l).

15. **Calcium Ions**: Calcium ions (Ca^{2+}) at Site I (240.33 ± 1.66 mg/l) were lower followed upwardly at the Site II (275.33 ± 3.09 mg/l).

16. **Sodium Ions**: Sodium ions (Na^+) at Site I (260.2 ± 5.3 mg/l) were the higher than at the Site II (238.66 ± 1.06 mg/l).

17. **Potassium Ions**: Potassium ions (K^+) at Site I (53.0 ± 1.05 mg/l) followed upwardly at the Site II (82.0 ± 1.35 mg/l).

18. **Magnesium Ions**: Magnesium ions (Mg^{2+}) at Site I (213.33 ± 1.76 mg/l) followed upwardly at the Site II (265.0 ± 2.51 mg/l).

19. **Sulphate Ions**: Sulphate ions (SO_4^{2+}) at Site I (303.0 ± 1.6 mg/l) followed upwardly at the Site II (403.66 ± 1.56 mg/l).

20. **Total alkalinity:** Total alkalinity at two sites was found to be at Site I (179.0 ± 1.52 mg/l) and at

Table 1. Physico-chemical Characterization of Sewage Effluents from two Selected Sites.

S. No.	Physico-chemical Parameters	Masani Nala	Sewage Farm
1	***Colour***	Blackish	Yellowish
2	***Odour***	Foul-pungent	Stinking-pungent
3	***Transparency***	Blackish	Yellowish
4	***Turbidity (NTU)***	14.0 ± 0.0	8.5 ± 0.07
5	***Temperature (^0C)***	26.66 ± 1.0	32.33 ± 1.54
6	***pH***	6.66 ± 0.09	7.5 ± 0.1
7	***Conductivity (dsm^{-1})***	630.0 ± 2.46	840.0 ± 0.12
8	***Free CO_2 (mg/l)***	170.0 ± 0.0	220.00 ± 1.12
9	***DO (mg/l)***	45.0 ± 1.0	76.33 ± 0.78
10	***BOD (mg/l)***	188.33 ± 0.78	200.0 ± 1.75
11	***COD (mg/l)***	370.0 ± 1.0	396.33 ± 0.66
12	***TSS (mg/l)***	1032.66 ± 2.33	1312.0 ± 2.18
13	***TDS (mg/l)***	1902.33 ± 2.4	2071.33 ± 2.4
14	***Cl^- (mg/l)***	620.66 ± 1.0	660.33 ± 1.75
15	***Ca^{2+} (mg/l)***	240.33 ± 1.66	275.33 ± 3.09
16	***Na^+ (mg/l)***	260.2 ± 5.3	238.66 ± 1.06
17	***K^+ (mg/l)***	53.0 ± 1.05	82.0 ± 1.35
18	***Mg^{2+} (mg/l)***	213.33 ± 1.76	265.0 ± 2.51
19	***SO_4^{--} (mg/l)***	303.0 ± 1.6	403.66 ± 1.56
20	***Total alkalinity (mg/l)***	170.0 ± 1.52	307.33 ± 2.72
21	***Inorganic P (mg/l)***	0.16 ± 0.0	0.18 ± 0.0
22	***Particulate P (mg/l)***	0.52 ± 0.08	1.0 ± 0.0
23	***Total Dissolved P* (mg/l)**	0.76 ± 0.01	1.0 ± 0.0
24	***Total Kjeldhal P (mg/l)***	2.41 ± 0.01	1.65 ± 0.0
25	***NH_3-N (mg/l)***	1.02 ± 0.01	1.1 ± 0.02
26	***NO_3^- -N (mg/l)***	18.0 ± 1.45	289.66 ± 1.2

Site II (315.33 ± 2.72 mg/l).

21. **Inorganic Phosphate:** Inorganic phosphate at two sites was found to be at Site I (0.17 ± 0.0 mg/l) and at Site II (0.19 ± 0.0 mg/l).

22. **Particulate Phosphate:** Particulate P at two sites was found to be at Site I (0.53 ± 0.08 mg/l) and at Site II (1.2 ± 0.0 mg/l).

23. **Total Dissolved Phosphate:** Total Dissolved P at two sites was found to be at Site I (0.81 ± 0.01 mg/l) and at Site II (1.1 ± 0.0 mg/l).

24. **Total Kjeldhal Phosphate:** Total Kjeldhal P at two sites was found to be at Site I (2.62 ± 0.01 mg/l) and at Site II (1.6 ± 0.0 mg/l).

25. **Ammonium Nitrate:** NH_3-N at two sites was found to be at Site I (1.12 ± 0.01 mg/l) and at Site II (1.24 ± 0.02 mg/l).

26. **Nitrate Nitrogen:** NO_3^- -N at two sites was found to be at Site I (20.33 ± 1.45 mg/l) and at Site II (311.66 ± 1.2).

The sources of odourous substances in potable water have been recorded by Sayato (1976), Singh (2003), Sharma (2004), Singh et al., (2008), Parashar (2011); Sharma et al., (2013a, b); Snehlata (2016); Parashar and Sharma (2017); Parashar et al., (2018); Sharma et al., (2018). As such water quality in River Yamuna observed showed foul-stinking to pungent smell owing to higher levels of TDS, chlorides, sulphates, SS and total hardness. In the present investigation it was found that most of the industries (printing, dyeing, silver polishing, betel-nut, chemical industries etc.) discharge their effluents in the Yamuna River through various drains, therefore, the two sites studied showed different colours in the water. The objectionable colour observed at the two sites was mainly due to the addition of city sewage as well as industrial effluents discharged at these sites.

The description presented in the present investigation reveals that the transparency varied with from bluish-black to yellowish-green tinge (Thakur, 2001; Sharma, 2004; Parashar, 2011; Sharma et al., 2013a, b; Snehlata, 2016; Parashar et al, 2018; Sharma et al., 2018).

The suspended solids increase the turbidity of river water (Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Parashar, 2011; Sharma et al., 2013a, b, 2018; Snehlata, 2016; Parashar et al, 2018). The maximum permitted turbidity limit by set by WHO (1984) for drinking water is 5 – 8 NTU and for other domestic purposes that should not exceed more than 25 NTU. Turbidity showed positive relation with temperature, BOD, COD, DS and SS. However, the negative correlation was found with DO and the nitrates as has also been reported by a number of workers (Singh et al., 1989a, b; Murthy et al., 1994; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Parashar, 2011; Sharma et al., 2013a, b; Snehlata, 2016; Parashar et al, 2018; Sharma et al., 2018).

The present study is in conformity of with the earlier findings (Rai, 1974a, b; Mitra, 1982; Yadav and Saxena, 1987; Sehgal and Siddiqui, 1989; Thakur, 2001; Sharma, 2004; Parashar, 2011; Sharma et al., 2013a, b; Snehlata, 2016; Parashar et al, 2017; Sharma et al., 2018) which reported water temperature variations contaminated by effluents from various types of industries. Our results clearly revealed that the presence of sewage effluents from city and industrial discharges is the major cause of rising temperature. With the rise of temperature there is decline in the DO levels. Also a rise in temperature leads to the speeding up of the physico-chemical reactions in water reducing the solubility of gases as such temperature showed strong positive correlation with turbidity, BOD, COD, DO, TSS and TDS and a mild correlation with pH, ammonia and nitrates. The strong correlation of temperature with turbidity, DS and SS is due to the quick evaporation of water when temperature is high. In concentrated water their density becomes high and leads to high turbidity as is shown by a number of workers (Thakur, 2001; Sharma, 2004; Parashar, 2011; Sharma et al., 2013a, b; Snehlata, 2016; Parashar et al, 2018; Sharma et al., 2018). The pH is another most important factor that influences the rate of biochemical conversion. Further, pH showed its positive correlation with all the parameters except the DO which might probably be due to that oxygen reduces the alkalinity of ammonical wastes (Dakshini and Soni, 1979; Mathur et al., 1987; Singh et al., 1988; Raiyani et al., 1994; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2004, 2008; Parashar, 2011; Sharma et al., 2013a, b; Snehlata, 2016; Parashar et al, 2018; Sharma et al., 2018).

According to WHO (1984) the DO should not be lower than 6 mg/l (3 mg/l ISI standard). During present study the DO showed a highly fluctuating trend as it exhibited a strong negative trend with temperature, BOD, COD, ammonia, DS and SS. Depletion of DO is an index of increased organic pollution. The water quality in respect to DO suggests that both the Sites I and II were highly polluted. The maximum permissible limit for BOD is 5 mg/l (WHO, 1984). BOD was found to be very high at Site II. It was found to have a very strong negative correlation with DO. High COD shows high accumulation of organic waste in the river. Broadly COD exhibited similar trends to BOD. COD was high at both the sites. Free Carbon dioxide showed the higher values. COD values were also observed to be high enough.

The above findings clearly showed undisputed fact that trends in DO, BOD and COD levels remained uniform and did not differ to a larger extent. Self-purification of rivers is one of their most remarkable character which leads eventually to a large extent on biochemical reactions going on in the water brought about by the activities of micro-organisms (bacteria and phyto-planktons) which replenish sufficient oxygen utilizing the organic matter as food and breakdown complex compounds to simpler and harmless products. The determination of BOD at various points in the river is necessary to assess the extent to which self-purification has proceeded. Total dissolved solids (TDS) also serve as indicator of sewage effluents which adds to turbidity and therefore, positively correlated with turbidity along with temperature, BOD and COD (Saxena and Chauhan, 1993; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Parashar, 2011; Sharma et al., 2013a, b; Snehlata, 2016; Parashar et al, 2018; Sharma et al., 2018). TDS also showed positive trend with hardness. Since the ground water of Mathura depicts higher values of hardness, this might be the reason for high TDS. Comparatively TDS was higher due to the continuous mixing of industrial effluents. Total suspended solids (TSS) showed almost a similar trend as that of TDS and were also found to be positively correlated with turbidity along with temperature, BOD and COD and hardness but showed a negative relation with that of DO. There seems to be an indirect negative relationship between TSS and DO involving the role of temperature and turbidity (Datar and Vashistha, 1992; Sunderrajan et al., 1994; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Parashar, 2011; Sharma et al., 2013a, b; Snehlata, 2016; Parashar et al, 2017; Sharma et al., 2018). TSS was, however, higher at Sites I and II probably due to the accumulation of large amount of un-decomposed organic and inorganic wastes indicating positive correlation of TSS with BOD which is in corroboration with the observations made by Mathur et al., (1987), Saxena and Chauhan, (1993), Shaji and Patel, (1990), Thakur (2001), Singh (2003), Sharma (2004), Singh et al., (2008), Parashar (2011), Sharma et al., (2013a, b); Snehlata (2016)), Parashar et al, (2017); Sharma et al., (2018);. Further, analysis of water revealed the presence of maximum amounts of electrolytes as such the conductivity was found to be very high. Regarding the Anion (-ve ions) Chloride ions (Cl^-) the variation was quite observable at the two sites whereas a reverse trend was observed with cations, i.e., Ca^{2+}, Mg^{2+}, K^+ and Na^+, where the maximum amount was found in water samples of Site II. The other ions like SO^{4--} matched with concentration of cations. Likewise, Cations (+ve ions) Calcium ions (Ca^{2+}), Sodium ions (Na^+), Potassium ions (K^+) and Magnesium ions (Mg^{2+}) also showed variable trends. The probable reason for the high degree of salinity might be due to the existing higher levels of salts of Ca, Mg, Na and K in the ground water along with the various chemical industries discharging their effluents and huge quantity of untreated city sewage in river water (Saxena and Chauhan, 1993; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Gautam, 2010; Parashar, 2011; Snehlata, 2016; Parashar et al, 2017). The total organic and inorganic solids present in industrial and sewage effluents affect the turbidity, conductivity and alkalinity, as highest amount of TS was observed a greater quantum of total solids has shown resemblance with above discussed parameters. As recorded earlier a similar finding was observed with TDS where a higher magnitude of TDS was recorded at Site II surprisingly enough followed by Site I because a huge amount of effluents are directly thrown by various industries and city sewage through a number of drains.

Seed Germination

The results in relation to the effect of different concentrations of Sewage Effluent (Sewage Farm) exposure on germination performance measured in terms of Germination Percent (GP) after 24, 48, 72, 96 and 120 hours of sowing have been shown in Tables 2 – 11. As indicated in the Table 2 (ANOVA Analysis - Germination Percent (GP) all the main effects viz., Crop, Treatment, Duration, and their interactions (A X B; A X C; B X C; A X B X C; A X D; B X D; A X B X D; C X D; A X C X D; B X C X D and A X B X C X D) were found to be highly significant at 0.01 and 0.05% level of probability and significant differences were noticed in the germination percentage of all the crops studied Tables 2 – 11.

Interaction Crop: The highest mean GP (47.04%) was recorded in the crop C3 followed by C1, C2 and lastly C4 with the lowest germination percentage of (39.29%). The crops were arranged in the following descending order on the basis of their respective GP irrespective of the treatment and seedling age (interaction Crop) (Table 3).

C3 Mustard (47.04%)>C1 Wheat (46.22%)>C2 Barley (39.31%)>C4 Broad bean (39.29%)

Interaction Treatment: A significant reduction in GP with increasing SE levels was observed irrespective of variety, treatment and seedling age (interaction Treatment). The reduction in GP was more pronounced after 75% of SE treatment. Further, with treatment GP was highest in controls (61.105%) followed by 50% SE (52.01%) showing increase over 25% SE while lowest (17.00%) with 100% SE (Table 4) and the treatments were arranged in the following descending order:

Control (61.10%)>50% (52.01%)>25% (50.92%)>75% (33.80%)>100% (17.00%)

Interaction Duration: It was observed that the crops showed first sign of germination at 24 hrs after sowing irrespective of crops and SE treatment (interaction Duration) and thereafter GP increased significantly with seedling age till 120 hrs (Table 5)

Table 2. * ANOVA Table* Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops.

Source of variation	DF	SS	MSS	F-value	Significance
Factor A (Crop)	**3**	4055.99	1351.99	631.88	*, **
Factor B (Treatment)	**4**	73941.92	18485.48	8639.6	*, **
Factor C (Duration)	**4**	151578.4	37894.61	17710.9	*, **
Factor A X B	**12**	18077.8	1506.48	704.08	*, **
Factor A X C	**12**	43626.52	3635.54	1699.15	*, **
Factor B X C	**16**	13995.17	874.69	408.81	*, **
Factor A X B X C	**48**	8792.95	183.18	85.61	*, **
Error	**200**	427.92	2.14		
Total	**299**	496.7			
SEM± 0.08 Grand Mean = 42.96					
Range of Germination	**Lower Range = 42.8 Upper Range = 43.13**				

*Significant at 0.05% Level of Probability; ** Significant at 0.01% Level of Probability; NS-Non-significant

Table 3. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Crop).

Crop	Germination Percentage	Range of Germination Percentage	
		Lower	**Upper**
C1 Wheat	46.22	45.89	46.56
C2 Barley	39.31	38.98	39.64
C3 Mustard	47.04	46.70	47.37
C4 Broad bean	39.29	38.96	39.62
SEM ± 0.169			

and the treatments were arranged in the following descending order:
120 hr (66.32%)>96 hr (60.87%)>72 hr (53.95%)>48 hr (26.19%)>24 hr (7.49%)

Interaction Crop X Treatment: The significant interaction of varieties with treatment (Crop X Treatment) is depicted in Table 6. All the four varieties showed a decrease in GP with increasing SE *treatment* however, the genotypic variations were quite evident. Surprisingly in 50% SE in leguminous crops C3 mustard and C4 broad bean enhancement in GP over Control was observed. Also in cereal crop C1 wheat in 50% SE treatment enhancement in GP over 25% SE was reported. Further, highest and lowest GP was observed in cereal crop C2 Barley as in Controls (80.318%) and 100% SE (1.27%). The four crops were arranged in the following descending order on the basis of their respective GP irrespective of the treatment:
C1 Wheat – Control (59.72%)>50% (58.66)>25% (50.83%)>75% (36.39%)>100% (25.52%)
C2 Barley – Control (80.31%)>25% (47.95)>50% (40.98%)>75% (26.03%)>100% (1.27%)
C3 Mustard –50% (56.19)>25% (52.90%)>Control (52.37%)>75% (41.51%)>100% (32.20%)

Table 4. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Treatment).

Treatment Sewage Effluent (%)	Germination Percentage	Range of Germination Percentage	
		Lower	**Upper**
Control DW	61.10	60.73	61.47
25%	50.92	50.55	51.29
50%	52.01	51.64	52.38
75%	33.80	33.43	34.17
100%	17.00	16.62	17.37
SEM ± 0.189			

Table 5. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Duration).

Duration (hours)	Germination Percentage	Range of Germination Percentage	
		Lower	**Upper**
24 hrs	7.49	7.12	7.87
48 hrs	26.19	25.82	26.56
72 hrs	53.95	53.58	54.32
96 hrs	60.87	60.50	61.25
120 hrs	66.32	65.94	66.69
SEM ± 0.189			

Table 6. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Crop X Treatment).

Treatment Sewage Effluent (%)	Crops			
	C1 WHEAT	**C2 BARLEY**	**C3 MUSTARD**	**C4 BROAD BEAN**
Control DW	59.72	80.31	52.37	52.0
25%	50.83	47.95	52.90	52.0
50%	58.66	40.98	56.19	52.2
75%	36.39	26.03	41.51	31.26
100%	25.52	1.27	32.20	9.0
SEM ± 0.378				

C4 Broad bean – 50% (52.2)>Control (52.0%)>25% (52.0%)>75% (31.26%)>100% (9.0%)
C3 Mustard>C1 Wheat>C4 Broad bean>C2 Barley

Interaction Crop X Duration: All the crop varieties showed an increase in GP (interaction Crop X Duration) exhibiting marked differences in their early seedling growth with advancement in seedling age and the effect of SE *treatment*, i.e., in general, tolerance to SE increased (Table 7) and were arranged in the following descending order on the basis of their respective GP irrespective of the

Table 7. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Crop X Duration).

Duration (hours)	Crops			
	C1 WHEAT	C2 BARLEY	C3 MUSTARD	C4 BROAD BEAN
24 hrs	0.26	29.68	**0.0**	**0.0**
48 hrs	32.66	39.44	32.66	**0.0**
72 hrs	53.57	42.46	54.57	65.2
96 hrs	67.98	42.40	67.92	65.2
120 hrs	76.66	42.56	79.98	66.06

Table 8. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Duration X Treatment).

Treatment Sewage Effluent (%)	Duration (hours)				
	24 hrs	**48 hrs**	**72 hrs**	**96 hrs**	**120 hrs**
Control DW	12.66	41.92	76.75	85.12	89.06
25%	10.12	30.02	64.38	72.50	77.58
50%	8.96	31.70	67.10	73.69	78.59
75%	5.71	19.85	40.37	47.15	55.91
100%	**0.00**	7.45	21.15	25.91	30.45
SEM ± 0.422					

duration:
C1 Wheat – 120 hr (76.66%)>96 hr (67.98%)>72 hr (53.57%)>48 hr(32.66%)>24 hr (0.26%)
C2 Barley – 120 hr (42.56%)>72 hr (42.46%)>96 hr (42.40%)>48 hr(39.44%)>24 hr (29.68%)
C3 Mustard – 120 hr (79.98%)>96 hr (67.92%)>72 hr (54.57%)>48 hr(32.66%)>24 hr (0.0%)
C4 Broad bean– 120 hr (66.06%)>96 hr (65.2%)>72 hr (65.2%)>48 hr(0.0%)>24 hr (0.0%)
C3 Mustard>C1 Wheat>C4 Broad bean>C2 Barley

Interaction Duration X Treatment: The interaction of Duration X Treatment (Table 8) shows that with increasing SE *treatment* level the deleterious salt effect was clearly observable which, however, declined with seedling age. Initially at 24 hours seedling age in control sets showed 12.66% germination but no germination was observed in the SE *treatment* sets of 100%. The treatments were arranged in the following descending order:
Control - 120 hr (89.06)>96 hr (85.12)>72 hr (76.75)>48 hr (41.92)>24 hr (12.66)
25% - 120 hr (77.58)>96 hr (72.50)>72 hr (64.38)>48 hr (30.02)>24 hr (10.12)
50% - 120 hr (78.59)>96 hr (73.69)>72 hr (67.10)>48 hr (19.85)>24 hr (8.96)
75% - 120 hr (55.91)>96 hr (47.15)>72 hr (40.37)>48 hr (35.75)>24 hr (5.71)
100% -120 hr (30.45)>96 hr (25.91)>72 hr (21.15)>48 hr (7.45)>24 hr (0.0)

Interaction Crop X Duration X Treatment: A review of the final interaction (Crop X Duration X Treatment) reveals that irrespective of salt concentration levels the GP had increased with seedling age and that the SE treatment had their individual effect depending upon the varying treatment levels. The GP was significantly inhibited by SE treatment in all the four crops however the degree of inhibition varied depending on the concentration of SE treatment (Tables 1 – 10). The lowest and highest at each duration from 24 to 120 hours and each treatment have been marked with lowest (*) and highest (**) asterisk in the Table 8 with lowest as 0.0% and highest 95.23 at 120 hours in 50% SE treatment in the crop C1 wheat. The

Table 9. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Crop X Duration X Treatment).

Crops	Duration (hours)	Treatment Sewage Effluent (%)				
		Control DW	**25%**	**50%**	**75%**	**100%**
C1 WHEAT	**24hrs**	0.37	0.35	0.43	0.32	0.05
	48hrs	52.02	35.28	38.88	25.50	11.62
	72hrs	67.95	58.96	71.90	38.45	30.60
	96hrs	86.95	75.30	86.90	52.45	38.34
	120hrs	**91.35****	84.30	**95.23****	53.79	47.01
C2 BARLEY	**24hrs**	**50.02****	**40.15****	**35.43****	**22.75****	**0.08****
	48hrs	**82.40****	**46.82****	41.34	26.11	0.53
	72hrs	**89.70****	**51.05***	**42.70***	**27.24***	**1.67***
	96hrs	**89.75****	**50.56***	**42.72***	**27.24***	**1.98***
	120hrs	89.75	**51.19***	**42.75***	**27.71***	**2.12***
C3 MUSTARD	**24hrs**	0.25	**0.00***	**0.00***	**0.00***	**0.00***
	48hrs	**33.27***	37.99	**46.62****	**27.81****	**17.67****
	72hrs	**62.73***	60.85	66.81	45.15	**37.34****
	96hrs	**77.13***	77.52	78.15	**58.48****	**48.34****
	120hrs	88.50	**88.18****	89.40	**76.15****	**57.67****
C4 BROAD BEAN	**24hrs**	**0.00***	**0.00***	**0.00***	**0.00***	**0.00***
	48hrs	**0.00***	**0.00***	**0.00***	**0.00***	**0.00****
	72hrs	86.67	**86.67****	**87.00****	**50.67****	15.00
	96hrs	86.67	**86.67****	**87.00****	50.67	15.00
	120hrs	86.67	86.67	87.00	55.00	15.00
SEM ± 0.845						

*, ** show lowest and highest values at each duration respectively.

lowest (0.0%) and the highest (57.67%) germination in 100% SE treatment have been reported in C3, C4 (lowest) and C3 (highest) respectively. At some hours in crops C1, C3 and C4 enhancement over the control have been observed in 25% and 50% SE treatment as in C3 at 48 hours in 25% SE treatment; in C1 at 24, 72, 96 and 120 hours in 50%; in C3 at 48 to 120 hours in 50% and in C4 from 72 to 120 hours in 50% SE treatment.

Seeing overall results it was recorded that the lowest GP (0.0%) was found in 25%, 50%, 75% and 100% SE treatment at 24 hours of germination in the crop C3 and C4 at 24 and 48 hours in controls as well as 25%, 50%, 75% and 100% SE treatment whereas highest (95.23%) was recorded in 50% SE treatment at 120 hours in C1. Also it has been observed that the crops C1 and C3 behaved better, even in 100% SE treatment concentration at 120 hours of seedling growth. Thus, crops show overall GP as:

C3 Mustard>C1 Wheat>C4 Broad bean>C2 Barley

Germination percentage as percent over control showed lowest rate (0.0%) at 24 hours in 100% in the four crops and the highest of (140.13%) at 48 hours in 50% in the crop C3 (Table 10). On the basis of percent over control varieties were placed as:

Table 10. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Percent over Control) (Crop X Duration X Treatmenjt).

Crops	Duration (hours)	Treatment Sewage Effluent (%)				
		Control DW	**25%**	**50%**	**75%**	**100%**
C1 WHEAT	**24hrs**	**100.00**	94.59	116.21	28.91	13.51
	48hrs	**100.00**	67.83	74.75	49.02	22.33
	72hrs	**100.00**	86.77	105.81	**56.58**	45.03
	96hrs	**100.00**	86.60	99.94	60.32	44.22
	120hrs	**100.00**	92.28	104.24	47.93	51.46
C2 BARLEY	**24hrs**	**100.00**	80.27	70.82	45.47	0.00
	48hrs	**100.00**	56.81	56.16	31.68	0.64
	72hrs	**100.00**	56.91	47.60	**30.36**	1.85
	96hrs	**100.00**	56.33	47.60	30.11	2.22
	120hrs	**100.00**	57.03	47.63	30.13	2.35
C3 MUSTARD	**24hrs**	**100.00**	0.00	0.00	0.00	0.00
	48hrs	**100.00**	114.18	140.13	83.59	53.10
	72hrs	**100.00**	97.00	106.50	**71.97**	59.52
	96hrs	**100.00**	100.49	101.31	75.82	62.67
	120hrs	**100.00**	99.64	101.01	86.04	65.16
C4 BROAD BEAN	**24hrs**	**100.00**	0.00	0.00	0.00	0.00
	48hrs	**100.00**	0.00	0.00	0.00	0.00
	72hrs	**100.00**	100.00	100.38	**58.46**	17.30
	96hrs	**100.00**	100.00	100.38	58.46	17.30
	120hrs	**100.00**	100.00	100.38	63.461	17.30
SEM ± 0.845						

C3 Mustard>C1 Wheat>C4 Broad bean>C2 Barley

Data recorded after 72 hours of presoaking the seeds in test solution have shown highest rate of GP (percent over control) 106.5 (+ 6.5) in 50% SE treatment in the crop C3 and lowest 1.85 (- 98.14) in 100% in C2 depict C3 growth of + 6.5% over the control and the overall better performance of the C3 in all the treatments (Table 11) and were arranged in the following descending order:

C1 Wheat – 50% (105.81 (+ 5.81))> Control (100%)>25% (86.77 (- 1322))>75% (56.58 (- 43.41))> 100% (45.03 (- 54.96))

C2 Barley –Control (100%)>25% (56.91 (- 43.09))> 50% (47.60 (- 52.39))>75% (30.36 (- 69.63))> 100% (1.85 (- 98.14))

C3 Mustard –50% (106.5 (+ 6.5))> Control (100%)>25% (97.0 (- 2.99))>75% (71.97 (- 28.02))> 100% (59.52 (- 40.47))

C4 Broad bean – 50% (100.38 (+ 0.38))> Control (100%)>25% (100.0 (- 0.0))>75% (58.46 (- 41.53))> 100% (17.3 (- 82.69))

Further, it was observed that 75% SE concentrations and also 72 hours of germination were found to be quite critical for the crops, therefore, on the basis of percent over control at 72 hours with 75% SE concentration the germination percentage in the four crops showed a trend as percent change over control: Mustard (71.97%), Broad bean (58.46), Wheat (56.58) and Barley

Table 11. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops as Percent over Control (Data recorded after 72 hours of presoaking the seeds in test solutions).

Crop	Treatment Sewage Effluent (%)				
	Control DW	**25%**	**50%**	**75%**	**100%**
C1 Wheat	**100**	86.77 *(- 13.22)	105.81 *(+5.81)	**56.58 *(- 43.41)**	45.03 *(-54.96)
C2 Barley	**100**	56.91 *(- 43.09)	47.60 *(- 52.39)	**30.36 *(- 69.63)**	**1.85 *(- 98.14)**
C3 Mustard	**100**	97.00 *(- 2.99)	**106.50 *(+6.50)**	**71.97 *(- 28.02)**	59.52 *(- 40.47)
C4 Broad bean	**100**	100.00 *(- 0.00)	100.38 *(+0.38)	**58.46 *(- 41.53)**	17.30 *(- 82.69)
SEM ± 0.845					

*Values in Parenthesis show Percent Increase (+)/Decrease (-) over Control in GP

Table 12. Effect of different levels of Sewage Effluent Exposure on Germination Percentage in the four Crops (Percent over Control).

Crop	Speed of germination index (SGI) Percent increase (+)/decrease (-) over Control				
	Treatment Sewage Effluent (%)				
	Control DW	**25%**	**50%**	**75%**	**100%**
C1 Wheat	**100**	81.68 ***(-18.31)**	94.60 *(**-5.39**)	**55.61 *(-44.38)**	38.61 *(**-61.38**)
C2 Barley	**100**	62.02 *(**-37.97**)	53.55 *(**-46.44**)	**34.17 *(-65.82)**	1.22 *(**-98.77**)
C3 Mustard	**100**	102.20 *(**+2.2**)	111.91 (**+11.91**)	**77.80 *(-22.19)**	59.62 *(**-40.37**)
C4 Broad bean	**100**	100.00 *(**±0.0**)	100.38 *(**+0.38**)	***59.29 (-40.7)**	17.30 *(**-82.69**)

*Values in Parenthesis show Percent Increase (+)/Decrease (-) over Control in GP.

(30.36) (Table 11). Finally on the basis of percent germination over control in critical level of 75% at 72 hours the crops were arranged in the following descending order:

GP: C3 Mustard (71.97)>C4 Broad bean (58.46)>C1 Wheat (56.58)>C2 Barley (30.36)

Speed of germination index (SGI)

Lastly, the results for Speed of Germination Index (SGI) have been depicted in the Table 12. The crops (C3 Mustard and C4 Broad bean at 25% and 50% SE treatment concentrations showed an increase (+) in GP of treated seeds over control but at higher concentrations of 75% and 100% SE treatment concentration a decrease (-) was reported in the two crops. In the crop C3 increase was found to be 2.2% in 25% concentration and at 50% concentration it rose to 11.91% whereas in crop C4 at 25% concentration it was same as that of control and at 50% concentration GP was slightly higher (0.38% over control). At higher concentrations of 75% and 100% SE treatment in the crop C3 decrease (-) of GP was found to be 22.19% and 40.37% over control respectively. In the crop C4 decrease (-) of GP at higher concentrations of 75% and 100% SE treatment was found to be quite higher in that 40.7% and 82.69% over control respectively (Table 12). On the other hand, in the two crops (C1 wheat and C2 Barley) there was no increase (+) in GP was observed and also the crops showed absolutely differential pattern in that in crop C2 decrease (-) was found to be quite sharp as compared to the crop C1. Thus, overall SGI results showed highest (111.91% over control) in the crop C4 Mustard at 50% SE treatment concentration whereas the lowest (1.22% over control) SGI was observed in the crop C2 Barley at 100% SE

Table 13. Effect of different levels of Sewage Effluent Exposure on Germination Percentage (GP) and Speed of Germination Index (SGI) in the four crops (Percent increase (+)/decrease (-) over Control at 72 hours and in 75% Sewage Effluent (SE) Concentration.

Crops	Germination Percentage (GP)	Speed of Germination Index (SGI)
C3 Mustard	71.97	77.8
C4 Broad bean	58.46	59.29
C1 Wheat	56.58	55.61
C2 Barley	30.36	34.17

treatment concentration (Table 12).

Further, it was observed that 75% SE concentrations and also 72 hours of germination were found to be quite critical for the crops, therefore, on the basis of percent over control at 72 hours with 75% SE concentration the germination percentage in the four crops showed a trend as percent change over control: Mustard (71.8%), Broad bean (59.29), Wheat (55.61) and Barley (34.17) (Table 12). Finally, on the basis of SGI over control in critical level of 75% at 72 hours the crops were arranged in the following descending order:

SGI: C3 Mustard (71.8) >C4 Broad bean (59.29)>C1 Wheat> (55.61)>C2 Barley (34.17)

Thus, overall results of GP and SGI proved that the crops Mustard and Broad bean showed more tolerant behavior than the crops Wheat and Barley towards Sewage Effluent irrigation with dilution in the concentration as 25%, 50% and 75% and that there was found to be a direct correlation between GP and SGI at critical SE level of 75% and duration 72 hours as follows (Table 13);

GP: C3 Mustard (71.97) >C4 Broad bean (58.46)>C1 Wheat (56.58)>C2 Barley (30.36)

SGI: C3 Mustard (71.8) >C4 Broad bean (59.29)>C1 Wheat (55.61)>C2 Barley (34.17)

DISCUSSION

Increasing urbanization and industrialization is posing the disposal of sewage effluents on agricultural land a serious problem all over the world (Parashar and Sharma, 2017). The continuous use of industrial effluents by people in the adjoining area has become a common practice which results in accumulation of industrial pollutants and toxic metals in soil to such a level that may become phytotoxic and hazardous for the life of animal and human beings (Singh, 2009). The polluted sewage effluent water inhibits enzyme action thus affecting first of all the first step of plant life i.e., germination of seeds (Shani et al., 1983; Parashar, 2011; Sharma et al., 2014a, b, c, 2016; Sharma, 2015, 2017; Snehlata, 2016; Parashar and Sharma, 2017). Besides, polluted sewage effluents also contain beneficial elements (N, P, K) as well as toxic metals (Cr, Ni, Zn, Cd, Pb, Hg, Pb and As) as reported earlier by several researchers (Mishra et al., 1998; Sharma, 2004; Parashar, 2011; Sharma, 2015, 2017; Snehlata, 2016; Parashar et al, 2017). Also increase in NH_4^+-N concentration in effluent due to the mineralization of easily decomposable nitrogenous substances present in the sludge resulting in the release of NH_4^+-N and later the decrease in the concentration of NH_4^+-N may be due to plant uptake and reduced rate of release of NH_4^+-N from sludge, fixation, and volatilization losses (Nagarajah, 1988).

The effluents along with N, P, K released higher amounts of NH_4^+-N. Besides, NO_3^--N recorded due to withholding of water and conversion of NH_4^+-N to NO_3^- -N (mineralization). The NO_3^--N concentration may be due to immobilization and denitrification by general soil micro-flora. A higher NO_3^--N concentration recorded may also be caused by oxidation of NH_4^+-N to NO_3^--N in the rhizosphere, resulting due to the excess proliferation of plant roots rendering the soil more oxidative (Sakai, 1970; Smith and Delaune, 1984). The present study revealed that the higher N content in the effluents released significantly higher N fraction through decomposition which can be considered as an organic manure and soil amendment if properly treated and diluted before being used for irrigating crops. Similarly, the addition of sludge to agricultural land has been reported to increase the yields of many plants (Sharma, 2004; Unnamalai et al., 2007; Parashar, 2011; Sharma, 2015, 2017; Parashar and Sharma, 2017).

In the present analysis investigation was undertaken to assess the effect of sewage effluent on water quality of Yamuna River at Mathura and its impact on germination and later seedling growth and metabolism (physiological as well as well biochemical) of the crop plants such as Wheat, Barley, Mustard and Broad bean crops usually cultivated in this area. In our laboratory several researchers working on different cereal and legume crops have shown similar work for quite a long time with different salts, heavy metals, city and industrial effluents (Sharma, 1982, 1987, 2015, 2017; Sharma, 2004; Nauhbar, 2005; Yadav, 2007; Rani, 2007; Gautam, 2009, 2010; Singh, 2009; Parashar, 2011; Snehlata, 2016; Sharma, 2015, 2017; Parashar and Sharma, 2017; Pathak, 2017; Pathak et al., 2017; Saraswat, 2017). The effects of city and industrial effluents have been well documented in various crops (Sahai et al., 1983; Rajendran, 1990; Sharma et al., 2000; Sharma, 2004; Indira and Mohanty, 2006; Mahapatro and Mohanty, 2007; Dalai and Mohanty, 2008) suggesting various degrees of dilution of effluents beneficial to the crops. Corroborating the present investigation, studies conducted by various other researchers (Kadioglu and Algur, 1990; Muthukumar and Arokiasamy, 1994; Subramani et al., 1995; Sharma, 2004; Dalai and Mohanty, 2008; Sharma, 2015, 2017; Parashar and Sharma, 2017) revealed that the lower effluent concentration stimulates the plant growth whereas inhibiting at higher concentrations. A large number of reviews (Kannabiran and Pragasam, 1993; Kumar, 1995; Kannan, 2001; Pragasam and Kannabiran, 2001a, b, 2004; Mishra and Pandey, 2002) are available with regards to the effect of sewage effluents in the laboratory experimentation with various commonly cultivated crop plants. The effects of industrial effluent on germination of seeds were attributed to the presence of bio-toxic substances which alters the seed-water interaction necessary for triggering enzyme activity (Baruah and Das, 1998; Sharma, 2004; Parashar, 2011). In our laboratory also while working on various crop plants effects of different industrial effluents were also reported by Sharma et al.., (2014a) textile waste water on seed germination and growth development of *Vicia faba* L; Sharma et al., (2014b) paper mill effluent on seed germination and seedling growth of *Cyamompis tetragonoloba* L; Sharma et al., (2014c) paper mill effluent on seed germination and seedling growth of *Vigna radiata* L; Sharma et al., (2016) Paper Mill Effluent on Seed Germination and Seedling Growth of *Vigna radiata* L which also corroborates present study. The view of retardation in seedling growth due to high concentration of the effluent was also observed by Sahai et al., (1983) in rice, Srivastava (1986) in *Cajanus cajan* L., Rajendran (1990) in *Helianthus annus* L., Sharma (2004) in wheat and sorghum. The bio-toxic effect of the effluents on seedlings was evident from the fact that there is overall decrease in germination percentage. The lower concentration of effluent (25% – 50%) has a stimulating effect on the seed germination of the crops studied.

The results in relation to the effect of different concentrations of sewage effluent exposure on level of sewage effluent exposure phyto-toxicity measured in terms of Germination Percentage and Seed Germination Index after 24, 48, 72, 96 and 120 hours of sowing have shown the level of sewage effluent exposure phyto-toxicity was significantly increased from control to 25%, 50%, 75% and 100% sewage effluent exposure treatments. The degree of level of sewage effluent exposure phyto-toxicity varied depending on the percentage concentration. Therefore, it is extremely necessary to treat the effluent properly before release to a river system for irrigation in agriculture to minimize harmful impact (Kumar, 1995; Mishra and Pandey, 2002; Sharma et al., 2002; Sharma, 2004; Parashar, 2011; Snehlata, 2016; Parashar et al, 2017). Studies undertaken by several workers on green gram, black gram, wheat, ragi, mustard, barley, broad bean and sorghum seedlings (Sharma, 2004; Indira and Mohanty; 2006; Mahapatro and Mohanty, 2007; Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017) indicated the injury to the crop seedlings at higher effluent concentrations. Overall, it has been observed that the cereal crops suffered more than non-cereal crops.

CONCLUDING REMARKS

The aim of this research is to investigate the effects of Sewage Effluents stress on seed germination, seedling growth and metabolism in the four important crops Wheat, Barley, Mustard and Broad bean commonly cultivated in this region. The effects of sewage effluent stresses were tested at germination and seedling growth of these crops as these are the key events for the establishment of plants under any prevailing environmental conditions. In general, the germination percentage with increasing concentration levels of the Sewage Effluent treatment was inhibited however, interestingly, stimulation has been observed in growth of the crops as increased germination percentage at moderate levels of Effluent concentration. This stimulation in growth may be attributed to the nutritional supplementation at lower concentration of salts present in the Effluents. However, significant differences were noticed in the germination percentage of the four crops studied with the legume crops Mustard and Broad bean showing better growth performance than the cereal crops Wheat and Barley. Thus, the effluent treatment from early imbibitional period onwards, caused more inhibition in the cereal crops compared to legume crops might be due to induced oxidative damage in membrane which increases the activity of anti-oxidative enzymes. The higher level of effluents caused inhibition of seed germination and activity of anti-oxidative enzymes decreased. Therefore, legume crops were found to be more tolerant than cereal crops. The results in relation to the effect of different concentrations of sewage effluent exposure on germination performance measured in terms of germination percentage (GP) and Speed of Germination Index (SGI) after 24, 48, 72, 96 and 120 hours of sowing have shown significant differences in the germination percentage of all the crops studied with their interactions. Further, data recorded after 72 hours of presoaking the seeds in test solution have shown highest rate of germination (percent over control) 106.5 (+ 6.5) in 50% sewage effluent treatment in the crop C3 and lowest 1.85 (-98.14) in 100% in C2 depict the overall better performance of the crop C3 in all the treatments. Still, overall results proved that the two legume crops Mustard and Broad bean showed more tolerant behavior than the cereal crops Wheat and Barley towards Sewage Effluent irrigation with dilution in the concentration as 25%, 50% and 75%. Thus, identification of plants which can resist and clean-up metals from soils is required to improve phyto-remediation technologies. Moreover, plants have been proposed as bio-monitors of soil contamination but also as bio-markers of the environmental risk of pollutants.

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