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Research Article

CHARACTERIZATION OF THERMAL POWER PLANT DISCHARGED WASTEWATER AND CITY SEWAGE WASTEWATER: THEIR POTENTIAL USE AS IRRIGANTS FOR URBAN AGRICULTURE

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ABSTRACT

A pot experiment was conducted to test the feasibility of growing mungbean (*Vigna radiata* (L.) Wilczek) cv. T9 with thermal power wastewater (TPPW) and city sewage wastewater (SW) as an alternative to ground water (GW). The optimum requirement of fertilizers (N and P) for the crop under wastewater irrigation was also worked out. Both the irrigation wastewaters met the prescribed irrigational quality levels as prescribed by the Bureau of Indian Standards (BIS). A control was also run simultaneously using tap water as ground water (GW). While studying the physio-morphological, yield and seed quality characteristics, it was observed that the plants receiving the wastewater recorded enhanced growth, higher photosynthetic efficiency and has an ameliorative effect on certain enzymatic and biochemical traits which manifested itself in terms of higher yield and seed yield merit. No adverse effect of wastewaters was reported on the seed quality. Therefore, both wastes may compensate the chemical fertilizer consumption and in addition be an alternative option of waste disposal, besides lowering the burden on the meagre fresh water resources available to farmers.

INTRODUCTION

Water deficit and pollution of the existing water bodies are critical environmental issues at present world over. Most of the countries including India have serious water shortages and about every 6th person lack access to clean water. As per WHO (2009) and Wyman (2013), exploded population growth rate, high industrialization and urbanization, shifts in food production practices, increased living standards and poor water use practices are interacting factors that influence all fresh water related issues/ crisis, food security and safe drinking water. In 2000, India's total renewable water resources were estimated at 1, 244 m^3/capita/year (Earth trends, 2001) and it was estimated that 40% of India's water resources were being withdrawn with 90% used for irrigation. Fast depletion of ground water reserves in India, coupled with severe water pollution has put India in a difficult position to provide sufficient fresh water for daily use. Fresh water is becoming a scarce commodity, because of its high demand in domestic, industrial and agriculture sectors.

Agriculture is the greatest user of water all over the world. The water consumption for crop irrigation amounts to 70% and in some cases 90%of the world water requirements (Kalavrouziotis et al., 2011). 70% of Indian population being dependent upon farming, the farmers have no option other than to grow their agriculture and horticulture crops either under rain fed conditions or wastewater due to its easy availability near cities and even smaller towns (Chalkoo et al., 2014). Wastewater not only offers an alternative water irrigation source, but also an opportunity to recycle plant nutrients.

On global basis, about 80% or more energy is produced out of fossil fuel like coal, oil and natural gas. In India, approximately 65% of electricity is generated out of coal fired thermal power plants, thereby generating enormous quantities of wastewater.

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Since, wastewater can't be used in industries and other places until applying costly techniques to clean it, the only option remains is agriculture. According to Ahmad (2017), use of wastewater for agricultural practices is a potential solution to reduce fresh water demand and a feasible option of various nutrients which are believed to have a positive effect on soil properties and crop production in a sustainable way.

Outside the town limits of Aligarh, huge quantities of wastewater are discharged daily by the Harduaganj thermal power plant, located 14 kms from Aligarh city and also by sewage pumping station of the city. In addition, Aligarh is a hub of lock manufacturing industries and is home to various agro based industrial units manufacturing edible oil and dairy products. The local farmers generally irrigate their agricultural crops using these wastewaters because of regular availability without bearing any cost (Iqbal et al., 2017). Therefore, its use not only solves the disposal problem to certain extent but also serves as a source of essential plant nutrients particularly the nitrogen as wastewaters are rich source of nitrogen particularly nitrate nitrogen (Sahay et al., 2019).

Legumes accumulate large quantities of nitrogen (N) in seeds, a major limiting factor for their yield. Thus, nutrients present in wastewater may serve as the substitute to chemical fertilizer (Al-Rasheed and Sherif, 2000). According to Gori et al., (2000) and Nagajyothi et al., (2009) use of wastewater for irrigation purposes may serve as an important source of mineral nutrients like nitrogen (N), phosphorus (P), sulphur (S), calcium (Ca) and magnesium (Mg) which are essential for normal growth and development of plants. According to Ogwueleka (2009), agriculture lands amended with the wastewater can be a way to return the organic matter and essential elements to soil which minimises the risk of environmental pollution and solving the problem of disposal of both liquid and solid waste. According to Sahay et al., (2014), plants have a range of potential mechanism at cellular level that might be involved in the detoxification and, thus tolerance to heavy metal stress by primarily avoiding the build-up of toxic concentration at sensitive sites within the cell and preventing the damaging effects.

Pulses, well known as grain legumes are valued for their richness in quality proteins, minerals and vitamins and are inseparable ingredient of the diet of majority of Indian population (Siag et al., 2005) which makes them essential along with cereals in daily human diet. Due to their high genetic potential to thrive well under varied environmental conditions and their soil ameliorative properties, they have become the most important component of the sustainable agriculture particularly in dry land areas (Shah et al., 2018). The productivity of pulses in India is considerably low when compared with the average global mean productivity of 496.4 kg ha-1 (FAOSTAT, 2014).

Mungbean, being one of the important pulse crops of India, is an excellent source of low cost and high-quality protein (Taylor et al., 2005) and contributes about 14% of the total protein of average diet of an Indian. Since mungbean enriches the soil by fixing atmospheric nitrogen through symbiosis with nitrogen fixing rhizobia (Dotaniya et al., 2014; Stevenson and Van kessel, 1996), thus is valuable both economically as well as nutritionally and is widely used in different cropping systems (Yaqub et al., 2010). However, the yield of mungbean has always remained low in spite of concerted efforts by breeders. This poor yield to a certain extent has been attributed to the fact that legumes are mostly grown on relatively dry land of low fertility with low levels of agronomic management. Therefore, it was felt in order to enhance the annual yield of this crop management support in terms of factors such as irrigation and nutrition needs to be provided (Jain 1988). Since wastewater application has reduced the excessive use of synthetic fertilizers at a greater extent (Akhter et al., 2019). Keeping in view these points, a study was undertaken to test the feasibility of growing mungbean under sewage wastewater (SW) and thermal power plant discharged wastewater (TPPW) as the worldwide use of waste water for crop irrigation is well documented by several workers (Al-jaloud1995; Rusan et al., 2007).

MATERIALS AND METHODS

A Pot experiment was conducted in the green house of Environmental Plant Physiology Laboratory, Department of Botany, Aligarh Muslim University, Aligarh situated at 270.88′ latitude and 780.08′ N longitude with an elevation of 178.45 m above the sea level. The experiment was conducted during the summer season. The soil used for pot filling was obtained from farmer's field and before filling, the soil was thoroughly mixed with farm yard manure. Seeds used in the experiment were procured from IARI (Indian Agricultural Research Institute) and surface sterilized with 0.01% aqueous solution of sodium hypochlorite (NaOCl) followed by repeated washings with double distilled water (DDW) and then dried in shade before sowing (Sauer and Burrough, 1986). The seeds were inoculated with specific rhizobium inoculum as per Subbarao (1982) and were sown in already soil filled pots of 10″diameter.

The aim of the experiment was to study the performance of three types of irrigation waters viz., sewage wastewater (SW), thermal power plant wastewater (TPPW) and ground water (Gw) supplemented with three fertilizer doses viz., N0P0, N_40P_30 and N_80P_60 on growth, physiology, yield and quality of *Vigna radiata* (L.) Wilzeck. The scheme of treatments applied in the experiment is given in Table 1.

Thermal power plant wastewater (TPPW) and sewage wastewater (SW) were collected from the leachate reservoir of Harduaganj thermal power plant located at a distance of 14 km from the experimental site and municipal sewage pump of the university campus. Tap water without any treatment was the source of groundwater (GW). The samples of wastewaters were analysed for different physical and chemical properties as per the standard procedure of the American Public Health Association (APHA, 2005) and were subsequently compared with permissible limits set by Indian standards (ISI, 1974). For soil analysis, a composite sample was collected before sowing and was finely ground in a blender and passed through 2-mm sieve, was dried in oven and analysed for various physico-chemical parameters as per Jackson (1973) and Gosh et al., (1983).

For the study of growth and physiological traits, three plants from each treatment were selected randomly at 30 and 45 DAS corresponding to vegetative and pod initiation stages respectively. The harvesting was done at 70 DAS at maturity. Collected plant sample especially the roots were washed gently with deionised water to wipe away all adhering foreign particles. Growth parameters studied were plant dry weight, leaf area, root dry weight and nodule dry weight. Leaf area was determined gravimetrically as per Watson (1958).

Physiological and biochemical characteristics studied were leaf nitrate reductase activity (Jaworski, 1971), carbonic anhydrase (Dwivedi and Randhawa, 1974), leaf nitrogen content (Lindner, 1944) and total chlorophyll content was also determined by acetone (80%) extraction method (Mac-Kinney, 1941). Photosynthetic rate and stomatal conductance of leaves were measured by LI-COR 6200 portable photosynthesis system (Fig. 1). The leaves were randomly selected and photosynthesis measurement was done at about 1100 $umol^{-2} s^{-1}$ and photosynthetic active radiation at 1100-1200 hours. The photosynthetic water use efficiency was also calculated by using data on photosynthetic rate and stomatal conductance (Das et al., 1999).

At harvest, total biological yield, pods per plant, 1000 seed weight, seed yield, harvest index and seed yield merit were also studied. Harvest index was calculated by dividing seed yield by biological yield, whereas the product of seed yield and harvest index gave seed yield merit. Seed protein was also estimated as per the method of Lowry et al., (1951).

RESULTS AND DISSCUSSION

A Summary of the physico-chemical characteristics of the three irrigation waters is given in the Table 1. The pH of all the three irrigation waters was within the permissible limits of Bureau of Indian standards (ISI, 1983) with pH ranging from 7.2-7.9. Since it a well know fact that the irrigation water having a pH outside the normal range may cause nutritional imbalance or may contain a toxic ion. Also, the pH is the main factor for rhizosphere environment and thus the normal alkaline pH in the present study may have influenced root growth nodulation and nutrient uptake (Fig. 2). Similarly, the concentration of inorganic nutrients viz., nitrate, phosphate, calcium, magnesium, potassium and chloride were more in sewage water (SW) as compared to thermal power plant wastewater (TPPWW) and ground water (GW) but were within the permissible limits of irrigation water quality set by food and agriculture organization (FAO, 2006, 2011) and those proposed by Ayers and Wescot (1994). The role of these nutrients in plant growth and healthy development of the soil is well documented (Hayat et al., 2000; Atafar et al., 2010). According to Singh et. al. (2012), the presence of excess nutrients in wastewater makes them an excellent source of supplementation which in turn leads to a lower need of inorganic fertilizers and less degradation of environment. As the concentration of sulphate (SO_4^{-2}) ion is primarily

Table 1. Scheme of treatments applied in the experiment.

Fertilizer Treatments (N and P Kg ha^{-1})	Irrigation waters			T. No	Treatments	T. No	Treatments	T. No	Treatments
	GW	TPPW	SW						
N0 P0 +	+	+	+	T1	GWN0P0	T4	GWN40P30	T7	GW N80P60
N40P30	+	+	+	T2	TPPW N0P0T5	T5	TPPW N40P30	T8	TPPW N80P60
N80 P60	+	+	+	T3	SW N0P0	T6	SW N40P30	T9	SW N80P60

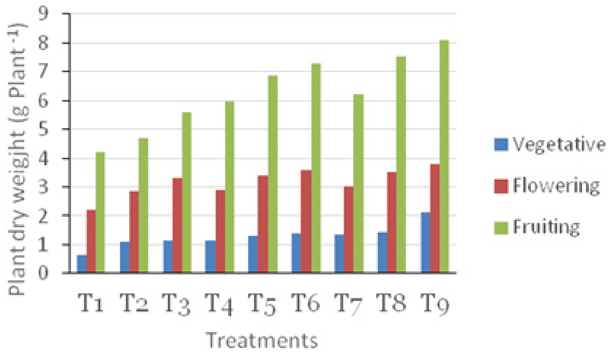

Fig 1. Plant dry weight.

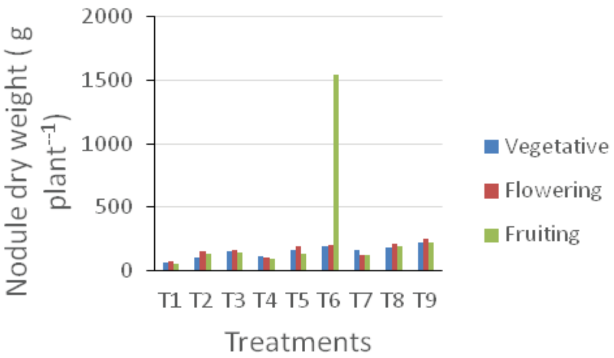

Fig 2. Nodule dry weight (g plant^{-1}).

responsible for maintaining cationic balance in plants, its concentration was well within the permissible limits (11-15 mgl^{-1}) in both the sewage wastewater and thermal power plant wastewater.

The sewage wastewater was having higher biological oxygen demand (BOD) and chemical oxygen demand (COD). As the values of the total dissolved solids (TDS), total suspended solids (TSS) and total solids (TS) were also high in sewage wastewater accounting for higher values of BOD and COD, thus indicating the pollution strength of sewage wastewater. The observations are on record where land application of wastewater leads to removal of pollutants by plant uptake, filtration and sedimentation (Shah et al., 2005; Tabassum et al., 2007). Wastewaters viz., sewage wastewater and thermal power plant wastewater proved more efficacious, enhancing almost all the growth parameters including plant dry weight, leaf area, root dry weight and nodule dry weight. The beneficial effect of wastewater on growth of plants may possibly be due to the presence and regular supply with each irrigation of the essential and beneficial nutrients in both sewage wastewater and thermal power plant wastewater particularly nitrogen which is the most important element limiting the plant growth as nitrogen controls the vegetative growth through protein metabolism which ensured optimum growth and development of plants (Faizan et al., 2014). The exploitation and the exploration of soil are ensured by rapid root growth and development. With the increased amount of nutrients in the soil, the plants have more chances to explore the soil for nutrients and water, resulting into enlargement, differentiation which in turn manifests in terms of increase in leaf area and production of dry matter. Its application might ensure the transfer of fertilizing elements particularly nitrogen (N), phosphorus (P), potassium (K^+), organic matter, micro and macronutrients into agricultural soil and has been reported to increase the crop yield (Kalra and Tripathy 1980; Nath et al., 2009). Thermal power plant wastewater applied with N_80P_60 (T8) has a synergistic effect in enhancing most of the growth parameters studied. This positive effect due to soil applied nitrogenous and phosphoric fertilisers along with thermal power discharged wastewater is inconformity with those of Tak et al., (2012).

Both types of wastewaters viz., thermal power wastewater and sewage wastewater proved more efficient than ground water in enhancing the physiological activities, which again may be due to presence of some of the essential nutrients shown in Tables 2 and 3. The physiological role of N, P, S, Mg and Ca supplemented through wastewater are well documented (Gardner et al., 1985) e.g. Mg which is an important constituent of porphyrin moiety of chlorophyll molecule and is important to photosynthesis, K acts as a cofactor in photosynthesis, while as chlorides are required in catalytic amount to carry out various enzymatic reaction in the cells. In addition, other essential nutrients like sulphur (S) could have also played a vital role in plant metabolism (Murphy and Boggan, 1988). In sulphur deficient

Table 2. Physico-chemical characteristics of soil before sowing used for the experiment and all determinations in mg l^{-1} (except for pH or as specified).

Texture	Sandy Loam
Colour	Light Brownish
CEC (meq/100 soil)	2.92
pH	7.9
Organic Carbon (%)	0.83
E C (u mhos/cm)	317
No3-N (g kg^{-1} soil)	0.296
Phosphorus (g kg^{-1} soils)	0.189
Potassium	27.19
Calcium	30.05
Magnesium	25.37
Sodium	11.73
Carbonate	76.43
Bicarbonate	39.21
Sulphate	15.24
Chloride	36.19

Table 3. Physico-chemical characteristics of ground water (GW) Thermal Power Plant Wastewater (TPPW) and Sewage Wastewater (SW) all determinations are in mgl^{-1} or as specified except for pH.

Characteristics	GW	TPPW	SW
pH	7.9	8.3	7.2
Electrical conductivity (ds/m)	0.74	0.88	0.95
Total Solids (TS)	819	1169	943
Total Dissolved Solids (TDS)	519	636	782
Total Suspended Solids (TSS)	792	918	1164
Dissolved Oxygen (DO)	5.42	3.23	2.19
Biological Oxygen Demand (BOD)	13.7	125.07	176.23
Chemical Oxygen Demand (COD)	29.04	61.92	119.57
Hardness	96.11	213.12	305.24
Magnesium (Mg^{++})	19.23	51.42	111.04
Calcium (Ca^{++})	25.23	41.36	44.96
Potassium (K^{+})	8.09	15.03	16.29
Sodium (Na^{+})	20.33	39.29	44.96
Bicarbonate (HCO^{-})	59.25	66.07	89.2
Carbonate (CO_3^{-})	27.51	54.63	109.12
Chloride (Cl^{-})	49.24	69.19	102.63
Phosphate (PO_4^{-})	0.25	0.96	1.09
Sulphate (SO_4^{-})	29.36	34.19	49.13
Nitrate N (NO_3)	0.89	1.2	1.92
Ammonium N (NH_3)	1.88	3.49	6.12

plants, protein content decreases, proteins are with lower proportions of methionine and cysteine but with higher proportions of other amino acids such as arginine and aspartate (Taket et al., 2010) and the lower sulphur content of the proteins influences the nutritional quality considerably (Arora and Luchra, 1970). The enhanced photosynthetic rate as a result of cumulative effect of essential nutrients present in wastewater may be due to increased leaf area and expansion (Fig. 3) which might have influenced the light absorption within the plant causing stimulation of PN, thereby optimizing the Co_2 assimilation and photosynthetic production (Iqbal et al., 2015). As per Campbell (1999), this could also be due to enhanced carbonic anhydrase activity (Fig. 4 and Fig. 5). Increased activity of carbonic anhydrase would make considerable quantity of additional Co_2 available for the process and thus for the synthesis of other compounds involved in photosynthesis such as chlorophyll (Fig. 6 and co-enzymes (Moroney et al., 2001). Photosynthetic water use efficiency which is a measure of rubisco activity (Vanden Boggard et al., 1995) was also enhanced as a result of higher mineral content of sewage wastewater (Fig. 7 and Fig. 8).

According to Afridi and Hewitt (1964), the first enzyme in plants for nitrate assimilation pathway i.e., NO_3 reductase is induced by its substrate NO_3

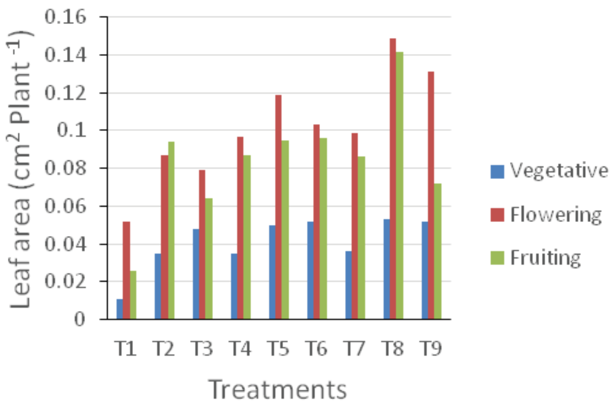

Fig 3. Leaf area (cm^2 plant^{-1}).

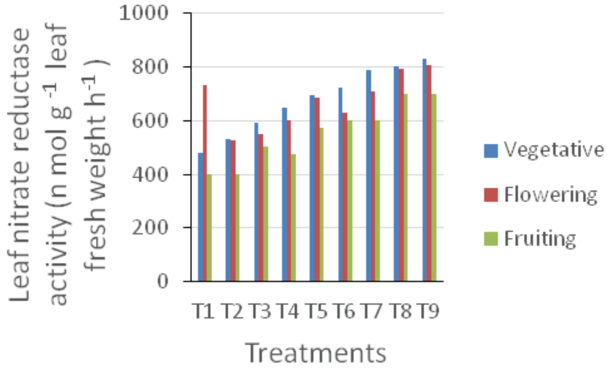

Fig 4. Leaf nitrate reductase activity.

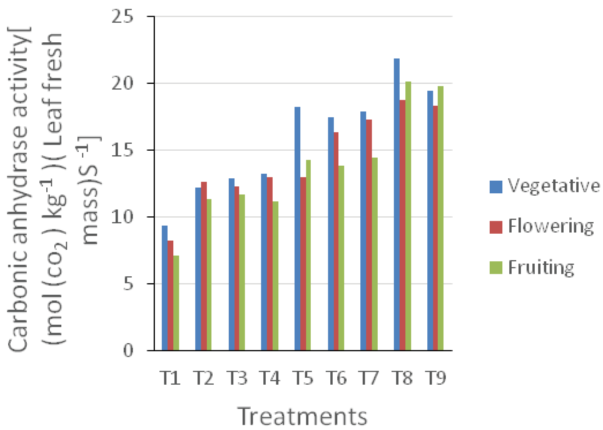

Fig 5. Carbonic anhydrase activity.

which is higher leaf nitrogen content. Thermal power plant irrigation resulted in the accumulation of more nitrogen content (Fig. 9 and Fig. 10) resulting in enhanced NO_3 reductase activity (Fig. 4). Further, there was a continuous decline in the concentration of three nutrients NPK with the age of plants. The development of seeds is a death message to older leaves as most of the mobile nutrients get translocated towards the developing organs (Bidwell, 1979), as it is a well-known fact that nutrients attain their highest concentration in plants during the early stage of growth and exhibit a decline towards maturity.

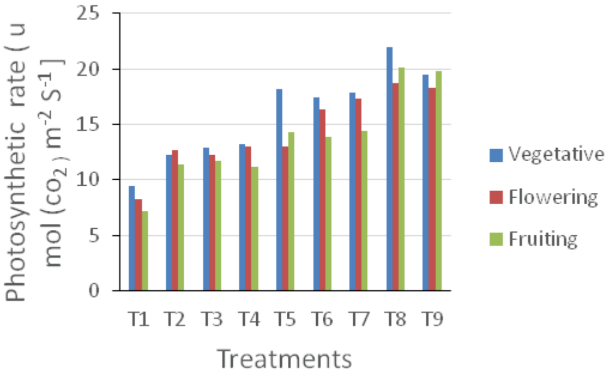

Fig 6. Photosynthetic rate.

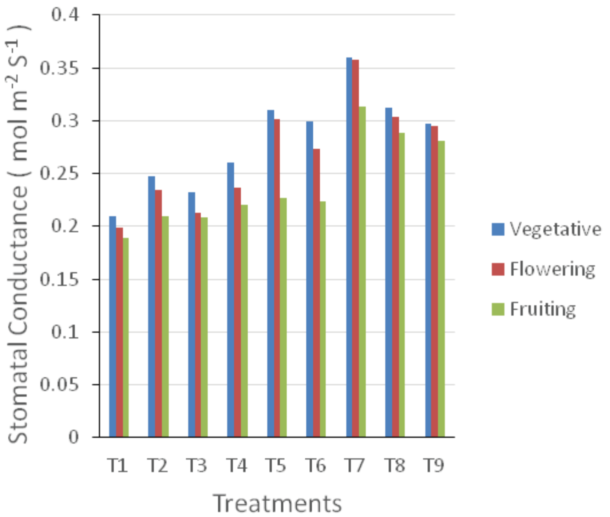

Fig 7. Stomatal conductance.

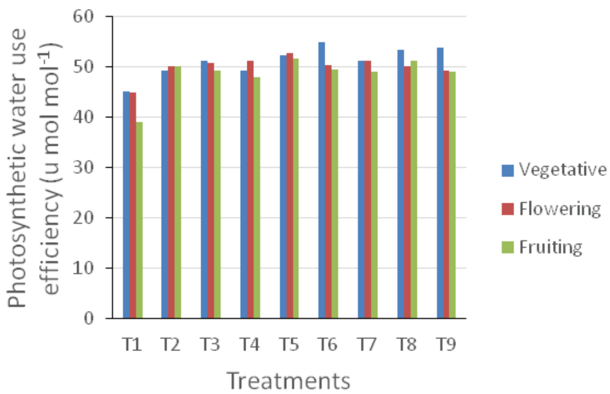

Fig 8. Photosynthetic water use efficiency.

Yield and Seed Quality Parameters

The beneficial effect of wastewaters in maximising growth may have sustained the improved partitioning of photosynthates which later on manifested in enhanced dry matter accumulation and yield characteristics (Parveen et al., 2013). These findings broadly confirm the findings of Tak, et al., (2013) and Sahay et al., (2013) while working on various types of industrial and sewage wastewater. As the wastewater proved efficient for almost all growth parameters including leaf area which ultimately helped the crop to harvest more radiant energy and produce more photosynthates ultimately leading to higher yields depending upon the efficiency of the cultivars for proper partitioning of photosynthates into reproductive and vegetative parts and retaining them till harvest in their seeds (Tak et al., 2014). This enhanced growth influenced the yield–attributing characteristics which were finally manifested in seed yield which is an important indicator of maximum biomass concentration in sinks (seeds) corroborating the earlier results of Bunting and Drennan (1966) who emphasized that the vegetative stage may have an important and direct effect on seed yield. However, the final seed yield in the sewage irrigated plants with highest fertilizer dose (T9) was less as compared to the plants irrigated with TPPW with the same dose of fertilizers (T8). This may be due to the possibility of nutrients crossing the critical limits (Akhter et al., 2008). It may be mentioned that the most of the parameters like leaf area and photosynthetic rate were maximally enhanced by this treatment. As already discussed, the enhanced photosynthetic rate ultimately helped the crop to harvest more radiant energy and produce more photosynthates leading

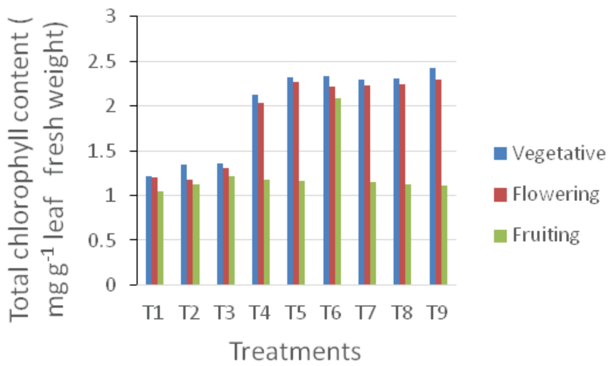

Fig 9. Total chlorophyll content.

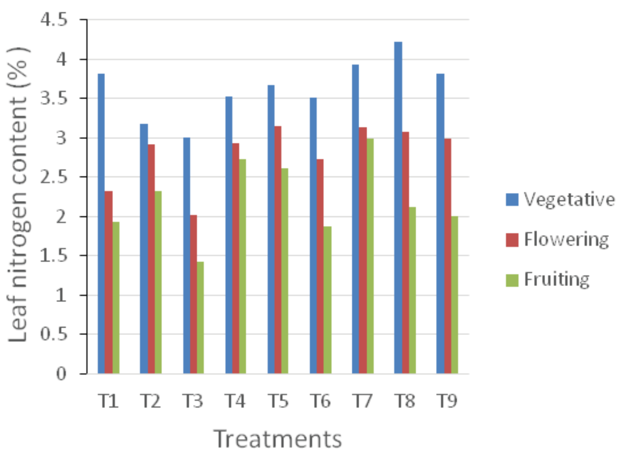

Fig 10. Leaf nitrogen content.

finally in the production of more pods, more seeds and finally more yield again an important attribute of biomass concentration. Further, seed yield merit as in the present study always provides a clear picture of photosynthate partitioning under increased levels of fertilizer and nutrients (Imsande, 1992). Contrarily to growth and yield, seed protein content remained non-significant (Fig. 11 - Fig. 15). The primary cause for this may be due "dilution effect". This dilution with growth effect occurs where even high quantities of nutrients appear to be less when expressed in percent basis (Moorby and Besford, 1983). Thus, the tendency to cross the levels of significance was nullified by the dilution effect due to increased seed yield.

Moreover, all the yield characteristics were significantly affected by the application of fertilizers. Both antagonistic and synergistic observations in fertiliser (N and P) interactions are not uncommon. It has been generally observed that an excess of one ion in the nutrient medium reduces the uptake of other ions. Therefore, a balance in the quantities of each of

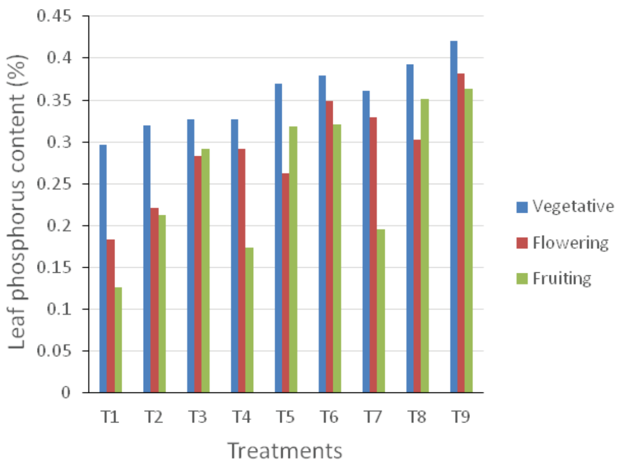

Fig 11. Leaf phosphorus content.

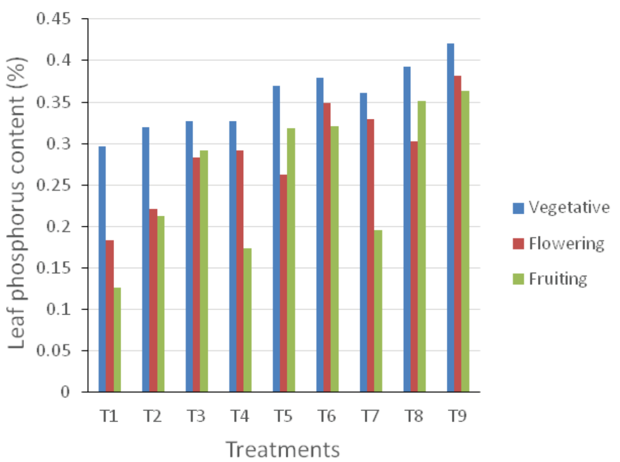

Fig 12. Leaf potassium content.

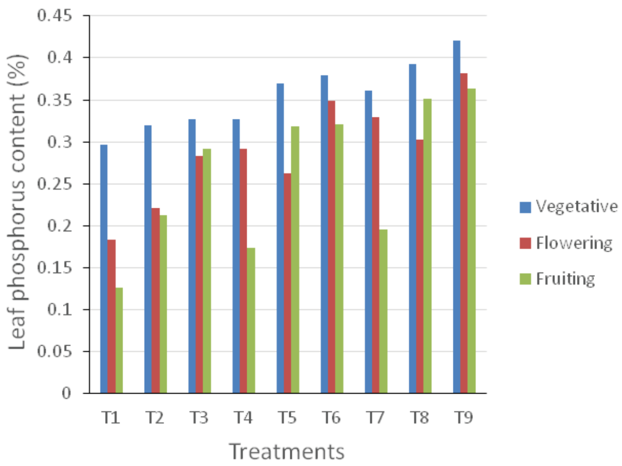

Fig 13. Seed yield merit.

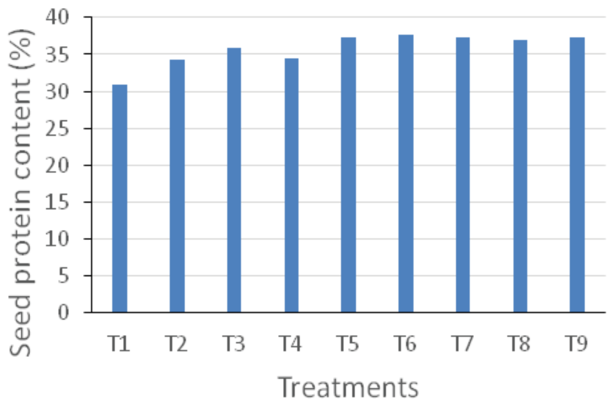

Fig 14. Seed protein content (%).

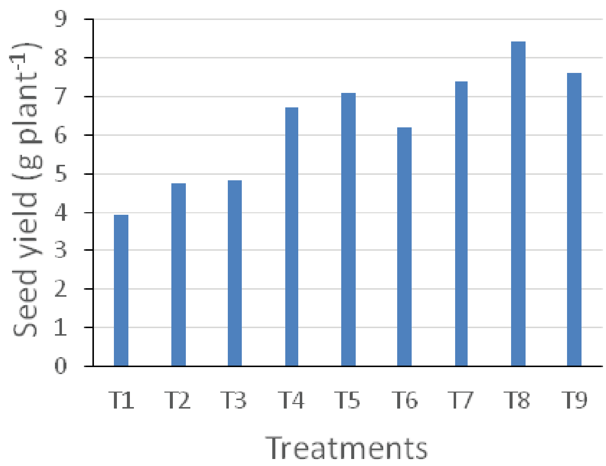

Fig 15. Seed yield (g plant^{-1}).

both nutrients has to be maintained by working out their optimum combination (Javid, 2002).

CONCLUSION

Overall, wastewater proved effective as compared to ground water in enhancing the yield of *Vigna*. Thermal power plant proved better than sewage wastewater indicating that it can be used for irrigating the farmer's field in the vicinity of Haduaganj Thermal Power Plant, therefore ensuring its proper disposal and avoiding the pollution of freshwater resources. Moreover, its use as an irrigant can also lower the economic burden of our marginal farmers.

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