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Original Research Paper

Water and Nutrient Harvesting from Thermal Plant Wastewater by Mustard

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ABSTRACT

A pot experiment was conducted to evaluate the impact of thermal power plant discharged wastewater for growth, yield and quality of mustard (*Brassica juncea* L. Czern and Coss). The water was analysed for various parameters viz., pH, total solids, BOD and COD, which were within permissible limits of Indian standards. The quality of some essential nutrients like nitrogen, potassium, phosphate, magnesium, chloride, calcium, carbonate, bicarbonate and sulphates was more in wastewater as compared to groundwater. The wastewater proved superior to groundwater as it enhanced almost all growth and yield parameters including the important oil content in seeds. However, wastewater, in general, recorded lower iodine, acid and saponification value as compared to groundwater. Interestingly, lower iodine value and acid value is considered good for mustard from commercial point of view.

INTRODUCTION

Water covers about 70% of our earth's surface. However, only about 0.5% is present as freshwater held in ground as groundwater or present as surface water in lakes, rivers, ponds and other water bodies (Cunnigham & Saigo 1995). There is continuous pressure and demand from industries, agriculture, commercial and domestic in addition to transport and recreation for freshwater. Moreover, due to rapid industrialization in India, being 7th in World, energy demand got intensified and therefore increased dependence on coal produced electricity which is about 65% of the total electricity generated in more than 80 thermal power plants. These power stations are dumping huge quantity of leachates annually in their surroundings.

Land applications of wastewater discharged from industries for crop cultivation presents an undesirable but easy and cheaper option for recycling of such water which can lower burden on already exhausted freshwater resources. Wastewater invariably contains some essential nutrients (Aziz et al. 1995). Therefore, its use may also lower pressure on fertilizer industry, if suited for crop growth. Although sufficient work has been done on the performance of crops irrigated with effluents discharged from various industries. The use of thermal power plant wastewater in agriculture has not received sufficient attention. Therefore, an experiment was conducted to study the comparative effect of thermal power plant discharged wastewater and groundwater along with nitrogen treatments on growth, yield, oil content and quality of mustard.

MATERIALS AND METHODS

A pot experiment was conducted during Rabi (winter season) in the net house of environmental plant physiology lab at Aligarh situated at 27°52' N latitude and 78°51'E longitude, and 189.45m altitude above the sea level. Wastewater was collected from the outlet of leachate reservoir of "Harduaganj Thermal Power Plant", situated 14km away from Aligarh city. The wastewater was transported in 50-litre plastic jerry canes while the tap water without any treatment was given as groundwater (GW) for the comparison.

The experiment was conducted according to simple randomized block design (CRBD) to test the suitability of thermal power plant wastewater as a source of irrigation water for mustard (*Brassica juncea* L. Czern and Coss). The crop was also supplemented with doses of nitrogen N_0, N_{40}, N_{60}, N_{80} given as urea. A uniform dose of phosphorus as single superphosphate and potassium as muriate of potash at the rate of 30kg/ha was applied at the time of sowing. Sowing and harvesting was done on the 4th November and 25th March respectively. Ten seeds surface sterilized were sown in earthen pots of 12" diameter to avoid germination failure. However, after germination only three seedlings with same distance were retained. Ten pots for each treatment were maintained for the random selection of plants during the study of growth, physiological and yield parameters.

At each time, 500 mL of water was applied on alternative days to each pot according to the size of pot and local

Table 1: Physico-chemical characters of groundwater (GW) and wastewater (WW). All units in mg/L except pH or as specified.

Parameters	GW	WW
pH	8	8.2
EC(ds/m)	0.78	0.89
TDS	512	647
TSS	391	603
TS	903	1250
BOD	2.06	16.53
COD	24	52
Mg	16.83	38.71
Ca	27.66	45.27
K	5	11
Na	14	38
HCO_3^-	57	73
CO_3^{2-}	13	27
Cl^-	65.32	91.42
PO_4^{3-}	0.07	0.89
NO_3-N	0.6	1.3
NH_3-N	2.77	6.88
SO_4^{2-}	53	67

Table 2: Physico-chemical characters of soil. All uits in mg/kg or as specified.

Parameters	Soil
CEC (meq/100g soil)	2.70
pH	8.10
Organic Carbon (%)	0.38
EC (µmhos/cm)	210.00
NO_3-N (g/kg soil)	0.250
Available Phosphorus (g/kg soil)	0.111
Potassium	11.00
Calcium	31.43
Magnesium	17.33
Sodium	9.55
Carbonate	18.33
Bicarbonate	57.00
Sulphate	17.55
Chloride	22.18

conditions. For studying physico-chemical characteristics of wastewater and groundwater, sampling was done after 15 days interval. These characteristics were studied according to the procedure outlined in the APHA (1998). The soil for pots was thoroughly mixed with farm yard manure and a composite soil sample was grinded by means of mortar and pestle and passed through a 2 mm sieve for determining various physico-chemical characteristics according to Ghosh et al. (1983).

The growth and physiological parameters were studied at vegetative (50 DAS), flowering (70 DAS) and fruiting (100 DAS) stages, while yield and its parameters at harvest. Nitrate reductase activity of the leaves was estimated following the method of Jaworski (1971), while leaf chlorophyll contents were estimated as per MacKinney (1941).

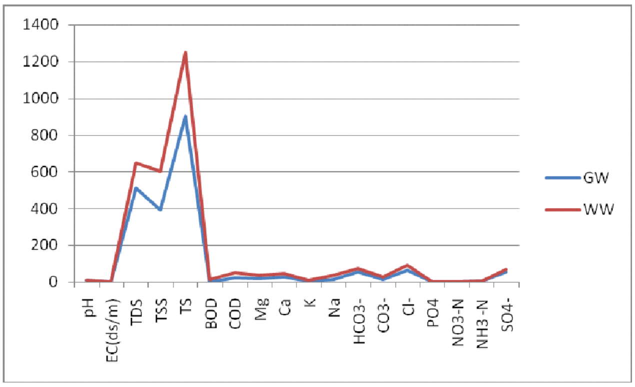

Fig 1: Physico-chemical characters of groundwater (GW) and wastewater (WW). All determinations in mg/L or as specified.

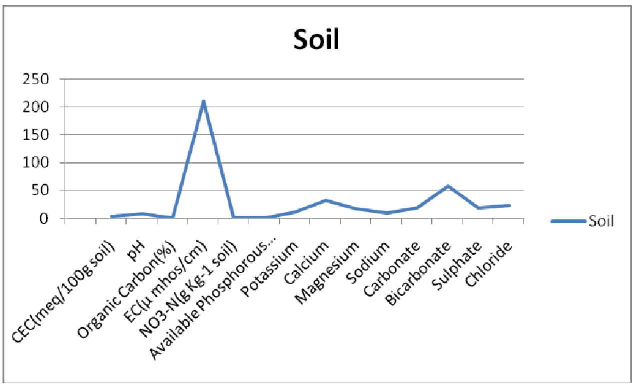

Fig. 2: Physico-chemical characters of soil. All determinations in **mg**[-1] or as specified.

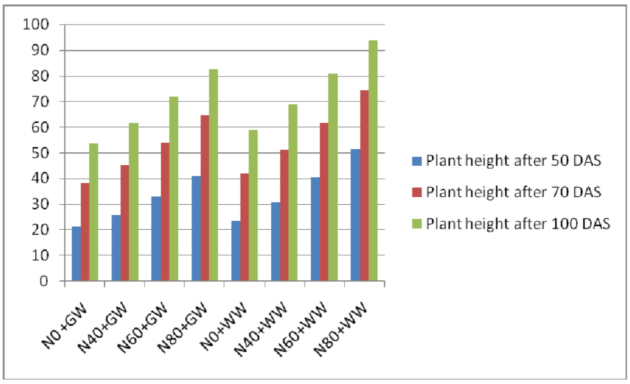

Fig 3(a): Effect of groundwater (GW) and wastewater (WW) on plant height (cm) of mustard (*Brassica Juncea*) grown with four levels of nitrogen.

Lindner (1944) method was applied to estimate leaf N contents. The seed samples, after separating from extraneous material, were crushed to get a fine meal for extracting the oil by Soxhlet apparatus, and oil quality like iodine, acid and saponification values were studied (Anonymous 1970). The data were analysed statistically according to Gomez & Gomez (1984). Analysis of variance was performed on the data and level of significance was determined for the treat-

Table 3: Effect of groundwater (GW) and wastewater (WW) on yield attributing parameters of mustard (*Brassica juncea*) grown with four levels of nitrogen.

Treatments	Biological yield (g Plant^{-1})	Pod number	Seed number Pod^{-1}	1000 seed weight (g)	Oil content (%)	Iodine value	Acid Value	Saponification Value
N_0 + GW	9.57	60	11.0	5.32	38.26	89.24	4.53	170.11
N_{40} + GW	11.72	76	12.4	5.76	42.59	91.75	4.96	177.85
N_{60} + GW	13.02	88	13.2	5.98	43.79	98.36	6.54	194.30
N_{80} + GW	15.25	108	14.3	6.32	41.26	95.74	5.59	185.65
N_0 + WW	11.67	85	11.8	5.79	39.52	88.72	4.12	166.43
N_{40} + WW	14.00	99	13.9	6.36	44.04	90.41	4.43	170.41
N_{60} + WW	15.94	114	15.0	6.58	45.57	97.84	5.09	186.11
N_{80} + WW	18.29	126	16.2	7.00	42.77	94.47	4.72	179.98
C.D.at 5%	0.53	7.14	0.30	0.43	0.35	0.53	0.25	0.74

A subscript value denotes amount of nitrogen applied in kg/ha.
A uniform basal dose of phosphorus (P) and potassium (K) was applied at the rate of 30 kg/ha each.

Table 4: Correlation co-efficient (r) values among different parameters and with yield of mustard.

Parameters	Leaf number	Leaf area	Plant dry weight	Total leaf dry weight	Pod number	Seed number	Seed yield	Leaf N content	Nitrate reductase activity	Total leaf chlorophyll content
Leaf number	1.000									
Leaf area	0.989**	1.000								
Plant dry weight	0.961**	0.990**	1.000							
Total leaf dry weight	0.977**	0.904**	0.985**	1.000						
Pod number	0.778*	0.829*	0.887**	0.827*	1.000					
Seed number	0.834**	0.891**	0.939**	0.871**	0.940**	1.000				
Seed yield	0.877**	0.930**	0.970**	0.920**	0.941**	0.988**	1.000			
Leaf N content	0.983**	0.977**	0.971**	0.964**	0.907**	0.941**	0.944**	1.000		
Nitrate reductase activity	0.952**	0.951**	0.954**	0.932**	0.923**	0.943**	0.946**	0.971**	1.000	
Total leaf chlorophyll content	0.985**	0.987**	0.985**	0.977**	0.922**	0.947**	0.956**	0.981**	0.969**	1.000

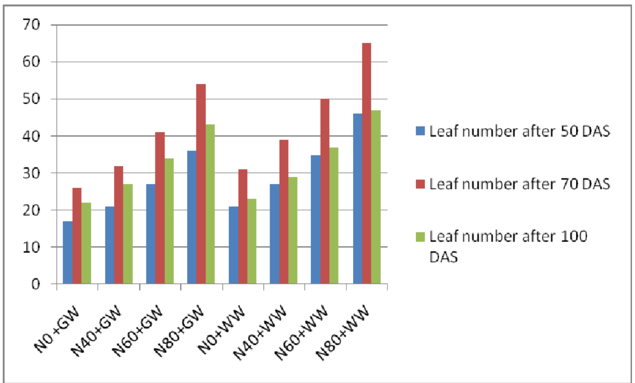

Fig. 3(b): Effect of groundwater (GW) and wastewater (WW) on leaf number per plant of mustard grown with four levels of nitrogen. DAS: Days after sowing.

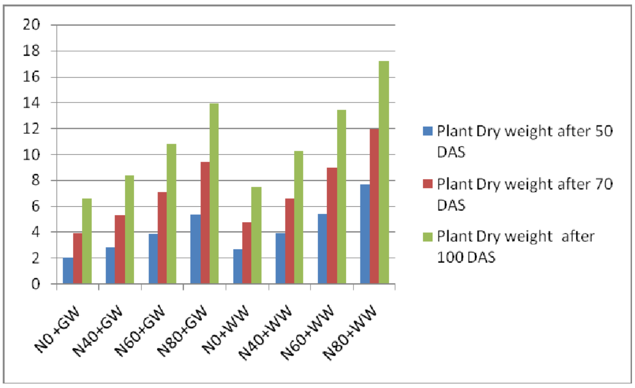

Fig. 3(c): Effect of groundwater (GW) and wastewater (WW) on plant dry weight (g plant^{-1}) of mustard grown with four levels of nitrogen.

ment. The data were declared significant if 'F' value observed was higher than the tabular 'F' value. For significant data least significant difference (LSD) was calculated to compare the mean values of the treatments. Linear regression analysis of seed yield with growth and yield attributing parameters was also carried out.

Table 5: Effect of groundwater (GW) and wastewater (WW) on seed yield (g $plant^{-1}$) and oil yield (mg $plant^{-1}$) of mustard (*Brassica juncea*) grown with four levels of nitrogen.

Treatments	Seed yield	Oil yield
N_0+ GW	4.58	175.23
N_{40}+ GW	7.00	298.13
N_{60}+ GW	8.19	358.64
N_{80} + GW	10.51	433.64
N_0+ WW	6.14	242.65
N_{40}+ WW	8.92	393.10
N_{60}+ WW	11.41	519.95
N_{80}+ WW	14.10	603.05
C.D at 5%	0.46	21.13

A subscript value denotes amount of nitrogen applied in kg/ha
A uniform basal dose of phosphorus (P) and potassium (K) was applied @of 30 kg/ha each.

RESULTS AND DISCUSSION

Physico-chemical properties of soil and irrigation water: The various physico-chemical properties of the two irrigation waters and soil are given in Table 1 and Figs. 1 and 2. The wastewater quality revealed its suitability for irrigation, the analysed parameters being within permissible limits of Bureau of Indian Standards (BIS). Wastewater possessed a comparatively higher value of TDS, TS, TSS, BOD, COD, and pH was almost same in both the waters. The quantity of some essential nutrients like NO_3-N, NH_3-N, P, K, Ca^{2+}, Mg^{2+}, Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-} was more in wastewater than the groundwater.

Crop growth and yield: Growth is an irreversible permanent change in volume or size of a living entity and is generally accompanied by a change in dry weight. Wastewater proved effective over groundwater for growth at 50, 70 and 100 DAS (Fig. 3a,b,c,d,e,f,g) for oil yield (Table 5, Fig. 8) and oil content (Table 3) at harvest due to the presence of various nutrients. The roots thus have more chances to explore the soil for nutrients and water. This may have resulted in increased differentiation, growth and development in the plants receiving wastewater noted by other workers (Aziz et al. 1999, Hayat et al. 2000, Adhikary & Gupta 2002 Javid et al. 2013). Nitrate reductase, which is the first enzyme in the nitrate assimilation pathway and is probably the best example of a plant enzyme induced by its substrate i.e., nitrate (Afridi & Hewitt 1964) was also significantly enhanced by wastewater application. Thus, the higher mineral status of the test plants and larger leaf area, with higher concentrations of chlorophyll stimulated the production of photosynthates, as evident from the higher dry matter accumulation (Fig. 3c).

Among the fertilizer treatments, WWN_{80} proved best for almost all growth enzymatic and biochemical parameters

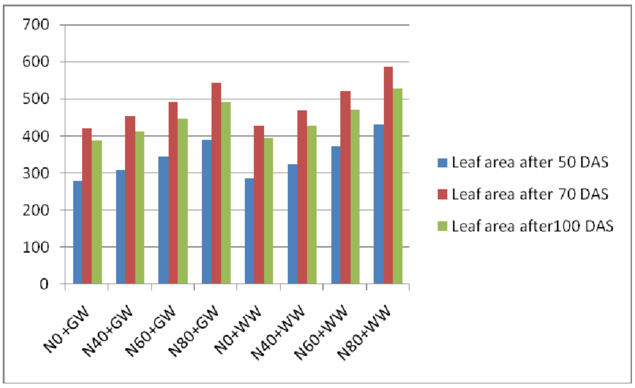

Fig.3(d): Effect of groundwater (GW) and wastewater (WW) on leaf area (cm^2 $plant^{-1}$) of mustard grown with four levels of nitrogen.

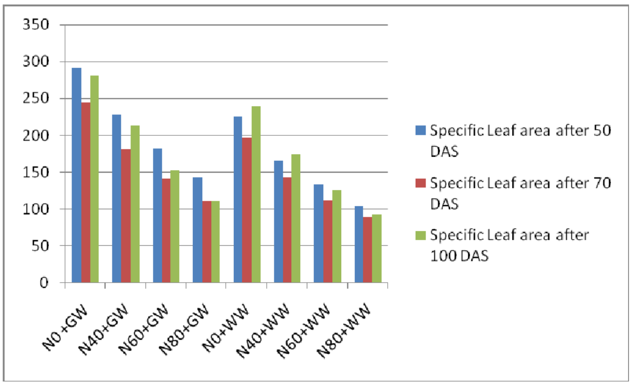

Fig. 3(e): Effect of groundwater (GW) and wastewater (WW) on specific leaf area (cm^2 g^{-1}) of mustard grown with four levels of nitrogen.

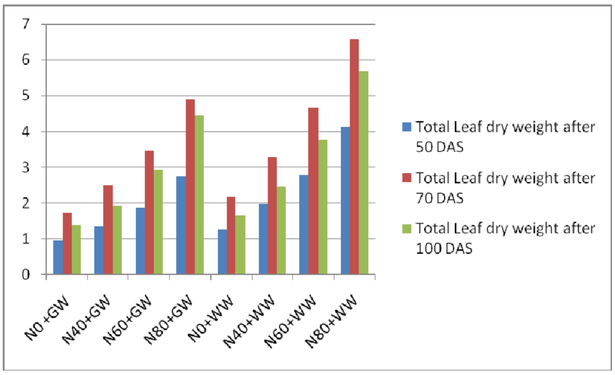

Fig. 3(f): Effect of groundwater (GW) and wastewater (WW) on total leaf dry weight (g $plant^{-1}$) of mustard grown with four levels of nitrogen.

studied together. It also enhanced yield parameters including seed and oil yield (Table 5). The superiority of WWN_{80} manifested itself early in better seed yield. The enhanced growth and finally yield as a result of this treatment may be due to the cumulative effect of nutrients present in

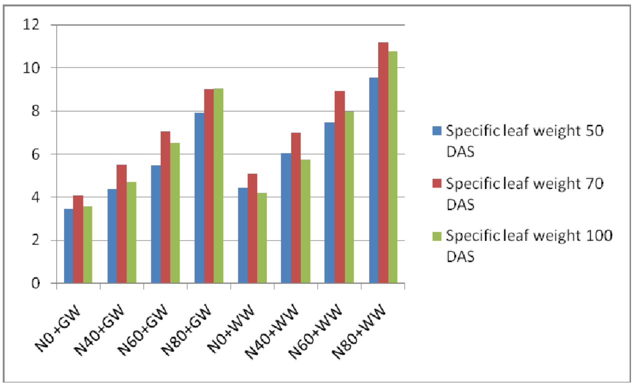

Fig. 3(g): Effect of groundwater (GW) and wastewater (WW) on specific leaf weight (mg cm^{-2}) of mustard grown with four levels of nitrogen.

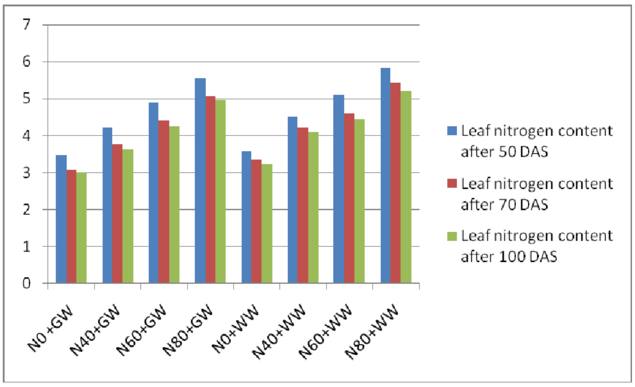

Fig. 5: Effect of groundwater (GW) and wastewater (WW) on leaf nitrogen content (%) of mustard grown with four levels of nitrogen.

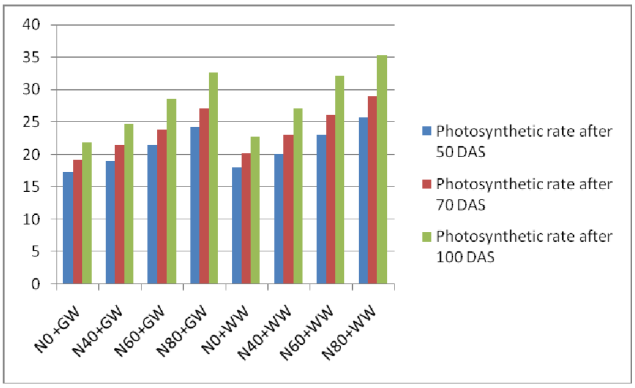

Fig. 4(a): Effect of groundwater (GW) and wastewater (WW) on photosynthetic rate (μ mol (CO_2) $m^{-2}s^{-1}$) of mustard grown with four levels of nitrogen.

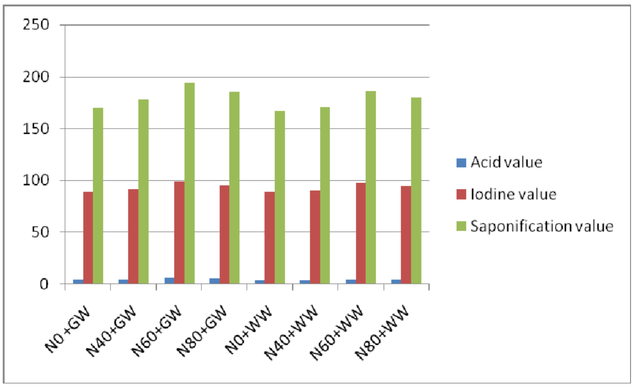

Fig. 6: Effect of groundwater (GW) and wastewater (WW) on acid value, iodine value and saponification value of mustard grown with four levels of nitrogen.

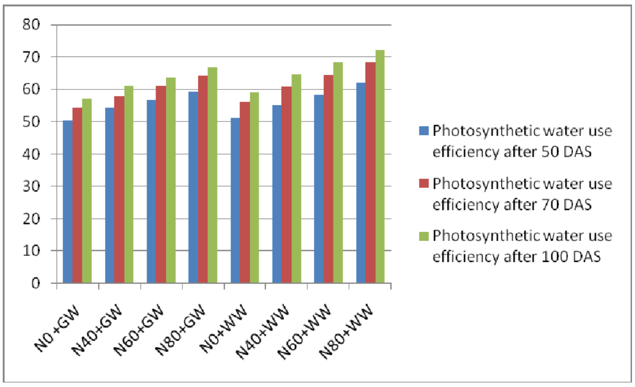

Fig. 4(b): Effect of groundwater (GW) and wastewater (WW) on photosynthetic water use efficiency (μ mol mol^{-1}) of mustard grown with four levels of nitrogen.

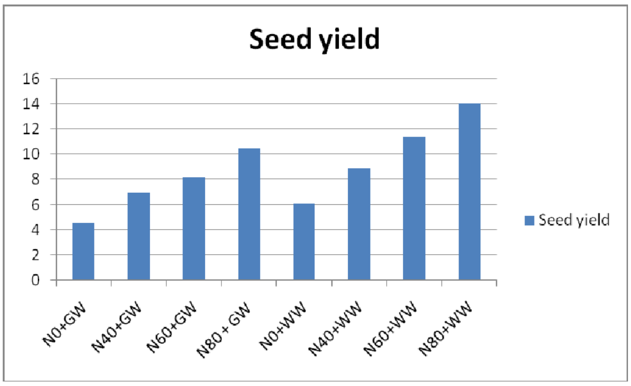

Fig. 7: Effect of groundwater (GW) and wastewater (WW) on seed yield (g $plant^{-1}$) of mustard grown with four levels of nitrogen.

wastewater as well as added dose of inorganic fertilizers. Also, vegetative growth consists mainly of growth and formation of new leaves, stem and roots. As meristematic tissues have a very active protein metabolism, photosynthates transported to these sites are used predominantly in the synthesis of nucleic acids and proteins. It is for this reason that during the vegetative stage, the optimum dose of nitrogen nutrition to a large extent controls the growth rate of plants. A high rate of growth only occurs when sufficient nitrogen together with other essential nutrients are available (Mengal

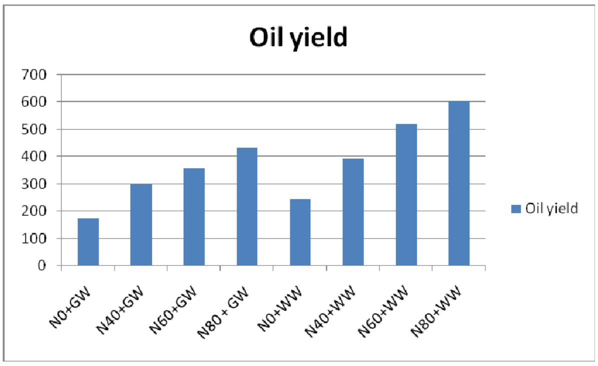

Fig. 8: Effect of groundwater (GW) and wastewater (WW) on oil yield (mg plant^{-1}) of mustard grown with four levels of nitrogen.

& Kirkby 1996) as was the case in the present study, which is revealed by positive correlation of growth and yield attributes with seed yield (Table 4).

Seed quality: Application of wastewater resulted in higher oil content (Table 3). This finding corroborates the findings of Aziz et al. (1999). Improvement in oil content resulting from wastewater irrigation could be attributed to the increased availability of nutrients as well as improved partitioning of photosynthates at the site of oil synthesis in treated plants. WWN_{60} recorded maximum oil content. The fertilizer dose N_{80} irrespective of water, proved deleterious as compared to N_{60}. Thus, irrespective of the type of irrigation water, higher levels of nitrogen proved deleterious for oil content in mustard.

The apparent explanation for the adverse effect of nitrogen may be the preferential utilization of carbon skeletons at the time of seed filling, towards protein synthesis rather than oil formation (Mazur et al. 1977). However, the positive effect of applied nitrogen on seed yield was so spectacular that it outbalanced the lower oil content value of seeds in providing considerably enhanced oil yield (Table 5 and Fig. 8), an obvious commercial advantage.

Contrary to growth, physiological attributes and yield parameters with wastewater gave low iodine, acid and saponification values (Fig. 6). However, low acid and iodine values are supposed to be good for commercial purpose in mustard, a positive point for using wastewater for this crop. Similarly, higher nitrogen level i.e., N_{80} irrespective of irrigation waters recorded lower iodine value. Similar decrease in iodine value as a result of higher nitrogen fertilization has been reported by Mohammad et al. (1985).

CONCLUSION

It may be concluded that thermal power plant discharged wastewater can be profitably used for cultivation of mustard as it proved more efficient in enhancing growth and finally yield. Thus, its application may lower pressures on fertilizer industry as well as on meagre freshwater resources of our country.

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