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SUITABILITY OF TWO WASTE PRODUCTS OF THERMAL POWER PLANT – WASTEWATER AND FLY ASH AS FERTILIZER AND IRRIGANT

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ABSTRACT

The reuse of two byproducts of thermal power plant viz, wastewater and fly ash in agriculture as substitute for an irrigant and fertilizer needs specific studies to evaluate their effects on different soils,crops and agro climatic conditions. However, fast depleting ground water resources coupled with India's severe water pollution has put India in a difficult position to provide sufficient water for agriculture. In order to mitigate the pollution effects of wastewater and fly ash and solve their disposal problem, a pot experiment was conducted in which an attempt was made to test the suitability of thermal power plant discharged wastewater and fly ash, supplemented with three doses,each of nitrogen, phosphorus and fly ash on leaf area, dry matter accumulation, yield and oil quality of flax (*Linumusitatissimum* L.) cv.Neelam. Wastewater application along with lower fertilizer and fly ash dose proved beneficial as it enhanced almost all parameters significantly as compared to higher doses applied with wastewater along with fly ash. Contrary to the physiological and yield characteristics, the iodine value was higher in plants irrigated with ground water. Wastewater met the irrigational quality requirement as its various physico- chemical characteristics were within the permissible limits of Indian standards and FAO.

KEY WORDS : Wastewater, Fly ash, Physico-Chemical Characterization, yield, Linum

INTRODUCTION

Water deficits and pollution of the existing water bodies are critical environmental issues at present. Most of the countries including India have serious water shortages and about every 6th person lack access to clean water (Tak *et al.,* 2010). According to Wyman (2013) and WHO (2009), the high consumption of water and the high demand for clean drinking water is created due to exploded population growth, industrialization and urbanization. In India and elsewhere there were violent conflicts over control of water resources and they may go out of hand if we don't learn to live under nature's budget.

On global basis about 80% or even more energy is produced out of fossil fuel like coal, oil and natural gas. In India, about 65% of the electricity generated is obtained out of coal fired thermal power plants generating enormous quantities of wastewater and fly ash. Since wastewater can not be used in industries and other places until applying costly techniques to clean it, the only option remains is agriculture which requires about 70% of total water consumption. The use of wastewater and fly ash; the two waste products generated from thermal power plants for irrigation and fertilization is in vogueand has become an important part of industrial and sewage wastewater disposal programme (Steel and Beigh, 1954; Tak *et al*., 2012). The use of wastewater for irrigation dates back to 14th and 15th centuries in the Milanese Marcites and in the Valencian Huertas, respectively (Soulie and Tremea, 1991). Limited and diluted form of wastewater from many industries can provide substantial essential nutrients in addition to its easy availability at least near the urban areas. This practice of using wastewater for irrigation is now common in many countries like USA, Europe, Egypt, China and Australia including India. The essential nutrients in the wastewater have resulted in the enhanced yield of various range of field crops including oleferous crops as well as vegetables, when compared to clean water irrigation (Akhter *et al.,* 2019). This Like wastewater, disposal of flyash is also a serious environmental problem. The Harduaganj thermal power plant located 14 kms from Aligarh city, generates large amount of wastewater and flyash, its continuous production affects the soil, water and air along with human health. According to MOEF, 2007; each year about 100 million tons of fly ash is produced in India and it was expected to generate 150-170 million tons in 2012. Furthermore it is likely to exceed 225 million tons in by 2017 (Singh, 2012). The utilization of fly ash in agriculture is recorded as 51% in the year 2007, primarily being used for recycling of nutrients by the farmers in the vicinity. The use of flyash in Indian agriculture has reported a great potency to improve crop productivitydue to its efficacy in modification of soil's physical and chemical health. As a matter of fact, fly ash practically consists of all the elements present in the soil except very low amount of organic carbon and nitrogen (Sahay *et al*., 2017). The utilization of fly ash instead of dumping it as a waste material can be both uneconomical and hazardous (Mohan *et al*., 2012). As such the application of fly ash on agriculture land realizes both benefits and negative effects in environment (Sahay *et al*., 2019). Therefore, agriculture offers one of the most suitable options for managing both wastewater and fly ash and the recycling of essential nutrients present in them as well (Ahmad, 2017).

Linseed (*Linum usitatissimum* L.) is an important cash crop in India and is primarily grown for its seed, which produces an important vegetable oil known as flax seed oil. The oil is rich in omega-3-fatty acids and is considered good for heart health. In addition, oil is mainly used in the linoleum, paint,printer's ink, soft soap and varnish industry (Hill, 1952). The linseed plant also furnishes a good quality fiber commonly called linen. The fibre is used in manufacture of canvas, coatings, durries, shirting and strong twines. The woody matter left after extraction of oil is converted into pulp for manufacture of paper (samba Murty and Subrahmanyam, 1989). It soil cake is an important cattle feed.

MATERIALS AND METHODS

A pot experiment was conducted in the net house of the Environmental Plant Physiology Laboratory, Department of Botany, Aligarh Muslim University, Aligarh, situated at 27.91^0N latitude and $78^0 08'$E longitude with an elevation of 178.45m above the sea level. The experiment was conducted during the winter season to study the comparative performance of linseed (*Linumu sitatissimmum* L.) cv. Neelam under two irrigation waters viz. waste water (Thermal power plant discharged wastewater) and Ground water (GW) and combined effect of threedoses, each of nitrogen, phosphorus and fly ash. The fertilizer doses were given in five combinations viz $N_0P_0FA_0$, $N_{68}P_{30}FA_{15}$, $N_{68}P_{60}FA_{15}$, $N_{90}P_{30}FA_{30}$, $N_{90}P_{60}FA_{30}$. The scheme of treatments is given in the Table 1. The crop was sown on 4th November 2014 and harvested on 1st April 2015. Seeds used in the experiment were procured from IARI (Indian Agriculture Research Institute) and surface sterilized with 0.01% sodium hypochlorite (Naocl) followed by repeated washings with double distilled water (DDW) and dried in shade before sowing (Sauer and Burrough, 1986). Wastewater and fly ash were collected from the outlet of leachate reservoir and fly ash pond of Harduaganj thermal power plant respectively, located at a distance of 14 km from the experimental site. Tap water without any treatment was used as a source of ground water. The samples of wastewater were analyzed for different physico-chemical characteristics as per the standard procedure of the American Public Health Association (APHA, 2005) and were subsequently compared with permissible limits set by Indian standards. The soil for pot filling was obtained from agricultural farm of the university. For pot filling, the soil was first thoroughly mixed with fly ash and farm yard manure and filled in pots of 10'' diameter. A composite soil and fly ash samples were taken before pot filling and were finely ground in a blender and passed through 2-mm sieve, were dried in oven and analyzed for various Physico-chemical parameters as per Jackson (1973) and Gosh *et al*. (1983).

For assessing the physiomorphological and biochemical traits, three plants from each treatment

Table 1. Scheme of treatments applied in the experiment

Fertilizer treatments (N, P and fly ash)	Irrigation waters	
	GW	WW
$N_0P_0FA_0$	+	+
$N_{68}P_{30}FA_{15}$	+	+
$N_{68}P_{60}FA_{15}$	+	+
$N_{90}P_{30}FA_{30}$	+	+
$N_{90}P_{60}FA_{30}$	+	+

were selected randomly at 50, 70 and 100 DAS corresponding to vegetative, flowering and fruiting stages respectively. Growth parameters studied were dry matter accumulation and leaf area. Leaf area was determined gravimetrically as per Watson (1958). At harvest, Seed yield, oil yield, harvest index were studied. For assessing the quality of the crop, oil content and its iodine value were studied as per Anonymous (1970).

The data was analyzed statistically according to Gomez and Gomez (1984). Analysis of variance was performed on the data and level of significance was determined for the treatment. The data were declared significant if F value observed was higher than tabulated F value. For significant data least significant difference (LSD) was calculated to compare the mean values of the treatments. Correlation analysis of seed yield with growth and yield attributing parameters was also worked out.

RESULTS AND DISSCUSSION

The physico-chemical analysis of two irrigation waters studied is givenin Table 2. The Indian Standards Institution (ISI, 1974, 1983) has recommended various standards for the disposal of industrial effluents. These standards comprise tolerance limits for the industrial effluents discharged into public sewers, inland surface waters, marine coastal areas and on to the land. Table 2, Indicates that waste water (thermal power plant discharged wastewater) has values within the permissible limits. The pH of both the irrigation waters was almost alkaline. As the pH is the main factor for rhizosphere environment and thus the normal pH as in the present study may have influenced root growth and thus enhanced the nutrient uptake (Akhter *et al.*, 2012). Since, it is a well known fact that the irrigation waters having a pH outside the normal range may cause nutritional imbalance or may contain a toxic ion. Waste water was having higher values of TS, TDS, TSS, BOD,

Table 2. Physico-chemical Characteristics of Ground Water (GW), Wastewater (WW) All determinations in mgl^{-1}or as specified

Parameters	GW	WW
PH	8.3	8.7
EC(ds/m)	0.78	0.99
TDS	534	677
TSS	366	554
TS	900	1231
BOD	4.10	15.17
COD	35	69
Mg	16.13	45.37
Ca	27.88	47.11
K	8	15
Na	21	47
HCO_3^-	61	89
CO_3^-	23	41
Cl^-	71.32	99.23
PO_4	0.09	0.97
NO_3-N	0.83	1.79
NH_3-N	3.78	7.21

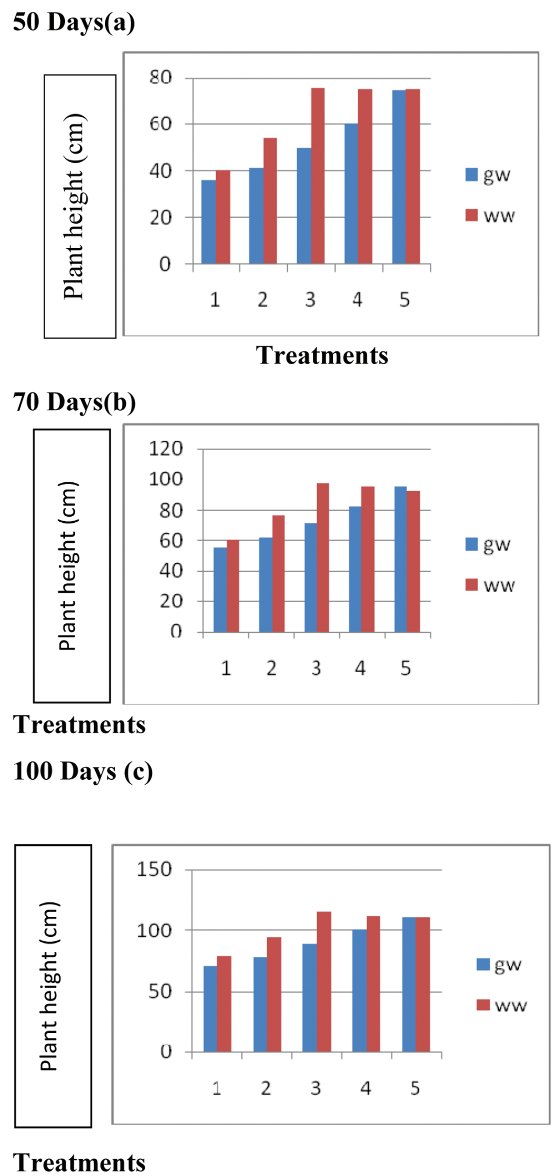


Fig. 1 (a, b, c). Effect of ground water (GW) and wastewater (WW) along with three doses of nitrogen, phosphorus and Fly ash on plant height (cm) of Linseed (*Linum usitatissimum* L.) CV. Neelam at 50, 70 and 100 days of sowing (DAS)

COD and EC, when compared to Ground water 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). Since the pollution strength of wastewater was higher as indicated by the higher values of BOD and COD, whose values are directly correlated with the values of TS, TDS, and TSS (Inam and Sahay, 2015). Plants have a unique genetic makeup which helps them to overcome the load of pollutants by simple uptake, sedimentation and filtration (Tabassum *et al*., 2015). In the present study NO_3-N was present in optimal quantity. Nitrogen plays a significant role in plants being important constituent of amino-acids and thus NO_3-N can be a significant source of nitrogen as it is found in most of wastewaters throughout the world (Chalkoo *et al*., 2014). The quantity of some essential nutrients like NO_3-N, P, K, Ca^{2+}, Mg^{+}, Cl^{-}, CO_3^{2-},SO_4^{2-} and $HCO3^{-}$ was also more in wastewater. According to Anzecc and Armcanz (2000), nitrogen is often the most limiting element in agricultural environment, thus required in large quantities which were sufficed by its enhanced amounts in the thermal power plant wastewater. The presence of excess nutrients in the wastewater makes them an excellent source of supplementation which in turn leads to lower need of inorganic fertilizers and prevents environment from degradation (Singh *et al*., 2012). The role of theses essential elements present in the wastewater in increasing the productivity is further supported from the works of Parveen *et al*. (2013) and Atafar *et al*. (2010).

Table 3. Physico-Chemical characteristics of soil and fly ash before mixing in soil. All determinations in mgl^{-1}, except for pH or as specified.

Parameters	Soil	fly ash
Texture	Sandy loam_	
CEC(meq/100gsoil)	2.90 _	
pH	7.80	8.2
Organic carbon (%)	0.88	0.522
EC(mhos/cm)	319.00	13.09
NO_3-N(gkg^{-1} soil)	0.290	0.091
Phosphorus(gkg^{-1}soil)	12.3	0.036
Potassium	27.3	13.00
Calcium	30.61	33.09
Magnesium	21.23	11.09
Sodium	11.72	15.31
Carbonate	69.38	61.09
Bicarbonate	128.0	094.27
Sulphate	15.28	28.56
Chloride	38.33	17.89

Wastewater proved superior to ground water particularly when given with lower fertilizer dose as compared to higher dose. It proved superior for leaf area,plant fresh weight and plant dry weight as also flower bud and flower number. The treatment with nitrogen @68 Kg ha^{-1} and fly ash @15t ha^{-1}($WWN_{68}P_{60}FA_{15}$) proved best. The significant role played by wastewater in lowering the fertilizer requirement is in conformity with the earlier studies of Iqbal *et al.* (2015). This is further supported by the works of Singh and Siddhqui (2003) and Jala and Goyal (2006), who reported that the application of fly ash enhances crop yield.

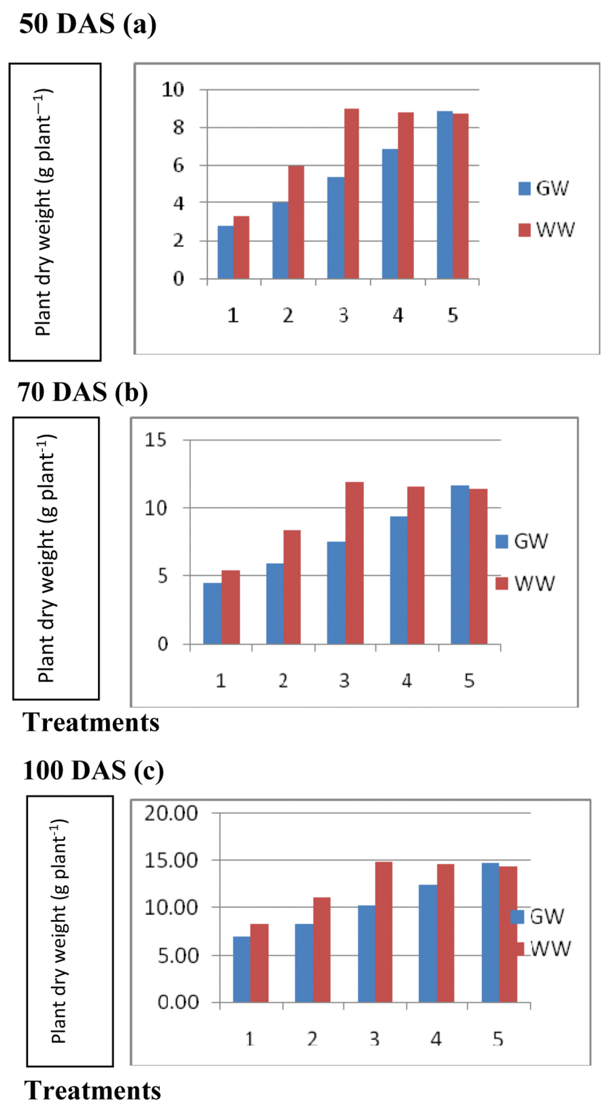


Fig. 2(a,b,c). Effect of ground water (GW) and wastewater (WW) along with three doses of nitrogen, phosphorus and Fly ash on Plant dry weight (g $plant^{-1}$) of Linseed (*Linum usitatissimum* L.) CV. Neelam at 50, 70 and 100 days of sowing (DAS)

The beneficial effect of wastewater and fly ash in maximizing growth characteristics may be due to the presence of micro and macro nutrients in fly ashand also their regular supply with each irrigation in wastewater which sustained better growth and development of plants. Thus, the fly ash and wastewater helped in maintaining the soil fertility manifested in better growth which possibly resulted in increased physiological activity and net primary productivity (Hewitt, 1963). The present data broadly confirms the findings of Hayat *et al*. (2000) and Tak *et al*.(2014) while working on industrial and sewage wastewaters. Also, growth parameters responded linearly to increasing fertilizer doses, when applied with ground water. On the other hand, higher fertilizer and fly ash dose proved detrimental for vegetative growth and yield parameters, when applied with wastewater. This implies that lower fertilizer dose was compensated by nutrients present in wastewater and in fly ash corroborating the earlier findings of Sahay *et al.* (2014).

The deleterious effect of wastewater when applied with higher fertilizer along with fly ash may be due to the nutrients crossing their critical limits. It may be pointed out here that increasing the level of Nitrogen nutrition may lead to an excess of soluble amino acids, which can't be used for growth processes because of relative shortage of other plant nutrients (Mengel and Kirkby, 1996). The treatment $WWN_{68}P_{60}FA_{15}$ proved best for almost all parameters. This is due to the fact that most of the growth parameters including leaf area were maximally enhanced by this treatment (Fig. 3,a,b,c)

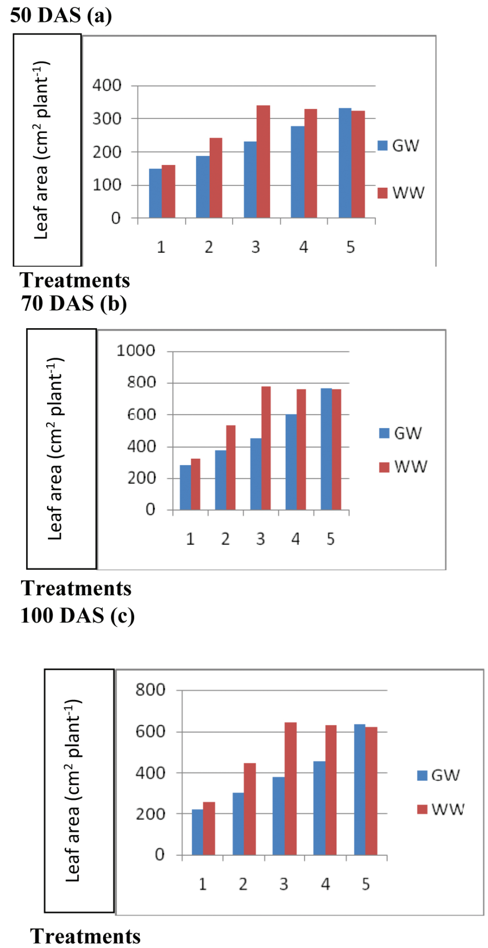


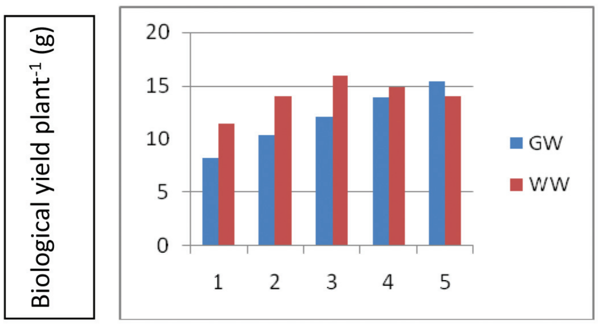
Fig. 3(a, b, c). Effect of ground water (GW) and wastewater (WW) along with three doses of nitrogen, phosphorus and Fly ash on leaf area (cm^2 $plant^{-1}$) of Linseed (*Linum usitatissimum* L.) CV. Neelam at 50, 70 and 100 days of sowing (DAS).

Table 4. Effect of ground water (GW) and Wastewater (WW) on yield characteristics of linseed (*Linum usitatissimum* L.) cv. Neelam grown with three levels each of nitrogen, phosphorus and fly ash

Treatments	Biological Yield plant^{-1}(g)	Capsules Plant^{-1}	Seed number Capsule^{-1}	1,000 seed weight	Seed yield Plant^{-1}(g)	Oil yield Plant^{-1}(g)	Oil content (%)	Iodine value
$N_0P_0FA_0$+ GW	8.23	40.0	8.6	7.01	4.30	1.73	40.24	123.95
$N_{68}P_{30}FA_{15}$+GW	10.40	52.3	9.8	7.28	5.81	2.55	43.99	129.22
$N_{68}P_{60}FA_{15}$+GW	12.10	66.6	10.6	7.30	6.90	3.11	45.14	134.42
$N_{90}P_{30}FA_{30}$++GW	14.00	81.0	11.3	7.64	8.30	3.42	41.22	125.76
$N_{90}P_{60}FA_{30}$ +GW	15.40	83.0	11.7	7.73	9.60	4.07	42.49	127.45
$N_0P_0FA_0$+WW	11.48	49.6	9.2	8.40	6.20	2.59	41.79	121.95
$N_{68}P_{30}FA_{15}$+WW	14.08	64.0	10.7	9.10	8.01	3.59	44.92	128.12
$N_{68}P_{60}FA_{15}$+WW	15.98	88.0	12.6	9.60	10.20	4.77	46.86	132.24
$N_{90}P_{30}FA_{30}$+WW	14.86	77.0	11.7	8.90	9.10	3.82	42.00	123.47
$N_{90}P_{60}FA_{30}$+WW	14.09	69.0	10.4	8.7	8.40	3.61	43.07	125.25
C.D at 5%	0.45	3.76	0.38	0.30	0.49	0.20	0.17	0.57

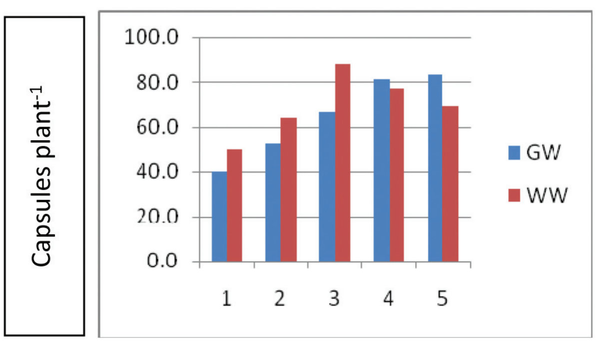
1. A subscript value denotes amount of nitrogen (in kg ha^{-1}), phosphorus (in kg ha^{-1}) and fly ash (in ta ha^{-1}).

which ultimately helped the crop to harvest more radiant energy and produce more photosynthates. This is clearly borne out by the production of higher dry weight in this treatment i.e. $WWN68P60FA_{15}$ (Fig. 2,a,b,c). Similarly,the increase in dry matter production due to fly ash and wastewater irrigation particularly during flowering and fruiting would be expected to lead to higher yields depending upon efficiency of cultivars for proper partitioning of photosynthates into reproductive and vegetative parts and retaining them till harvest in their seeds (Akhter *et al.*, 2008).



Treatments

Fig. 4. Effect of ground water (GW) and wastewater (WW) on Biological yield plant^{-1} (g) of Linseed (Linumusitatissimum L.) CV. Neelam grown with three levels each of nitrogen, phosphorus and Fly ash

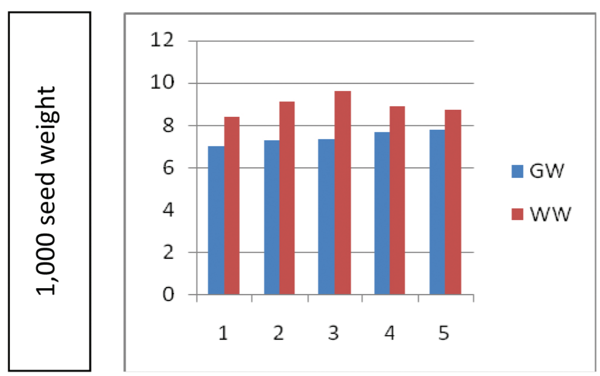


Treatments

Fig. 5. Effect of ground water (GW) and wastewater (WW) on capsules plant^{-1} of Linseed (*Linum usitatissimum* L.) CV. Neelam grown with three levels each of nitrogen, phosphorus and Fly ash

Like growth,the treatment $WWN_{68}P_{60}FA_{15}$ significantly enhanced capsule number, seed number and 1,000 seed weight. The positive correlation of the growth and yield attributing parameters exhibited their cumulative effect in the form of enhanced seed yield (Fig. 7) which is further confirmed by co-relation analysis of seed yield with growth and yield attributing parameters (Table 4). The increase in seed yield per plant produced by $WWN_{68}P_{60}FA_{15}$over $GWN_{90}P_{60}$ was 6.25%. Thus,it may be pointed out that higher seed yield can be obtained with N_{68} when applied withfly ash and wastewater indicating the suitability of fly ash and wastewater as a substitute for inorganic fertilizer and freshwater irrigant, as both were responsible for the saving of about 12 kgha^{-1} of nitrogenous fertilizer.

Higher oil content was recorded in seeds of wastewater irrigated plants as compared to ground water with $WWN_{68}P_{60}FA_{15}$. This is in conformity with earlier studies of Aziz *et al*. (1999) while



Treatments

Fig. 6. Effect of ground water (GW) and wastewater (WW) on 1,000 seed weight of Linseed (*Linum usitatissimum* L.) CV. Neelam grown with three levels each of nitrogen, phosphorus and Fly ash

Table 5. Correlation coefficient (r) values among different parameters and with yield in linseed at 100 DAS

Parameters	Leaf number	Leaf area	Plant dry weight	Total leaf dry Weight	Capsule number	Seed number	Seed yield
Leaf number	1.000						
Leaf area	0.990**	1.000					
Plant dry weight	0.999**	0.985**	1.000				
Total leaf dry weight	0.993**	0.992**	0.990**	1.000			
Capsule number	0.992**	0.981**	0.993**	0.993**	1.000		
Seed number	0.766**	0.752*	0.786**	0.764**	0.815**	1.000	
Seed yield	0.905**	0.888**	0.920**	0.882**	0.915**	0.901**	1.000

working on mustard and refinery wastewater. The deleterious effect of higher nitrogen levels on oil content in linseed corroborates some of the earlier findings reported elsewhere (Reddiah *et al.*, 1993; Sarode *et al.*, 1997). 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; Kalra and Tripathi, 1980 and Chourasia *et al.*, 1992) on rape seed, sunflower and linseed respectively.

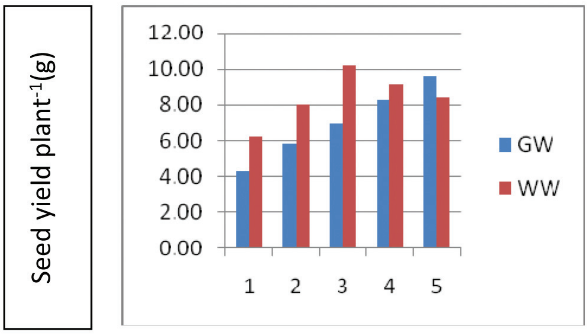


Fig. 7. Effect of ground water (GW) and wastewater (WW) on Seed yield plant^{-1} (g) of Linseed (*Linum usitatissimum* L.) CV. Neelam grown with three levels each of nitrogen, phosphorus and Fly ash.

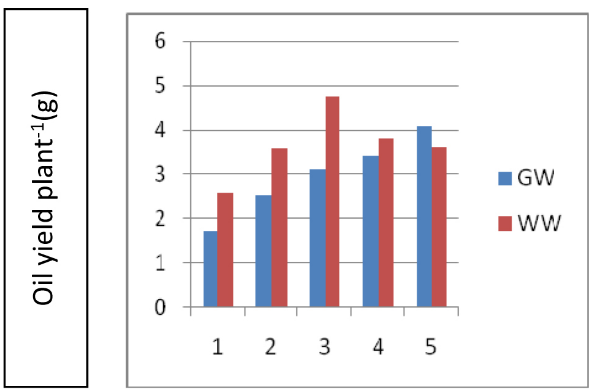


Fig. 8. Effect of ground water (GW) and wastewater (WW) on oil yield plant^{-1} (g) of Linseed (*Linum usitatissimum* L.) CV. grown with three levels each of nitrogen, phosphorus and Fly ash

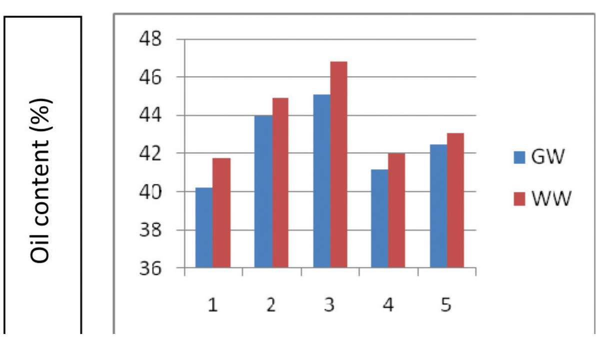


Fig. 9. Effect of ground water (GW) and wastewater (WW) on oil content (%) of Linseed (*Linum usitatissimum* L.) CV. grown with three levels each of nitrogen, phosphorus and Fly ash

Contrary to growth and yield parameters, wastewater irrigated plants recorded comparatively lower iodine value compared to ground water. Also, increase in nitrogen fertilization lead to decreased iodine value confirming the findings of Dybing (1964) and Singh and Singh (1978). This decrease in iodine value as a result of cumulative effect of nitrogen and wastewater is considered good as for as varnish industry is concerned.

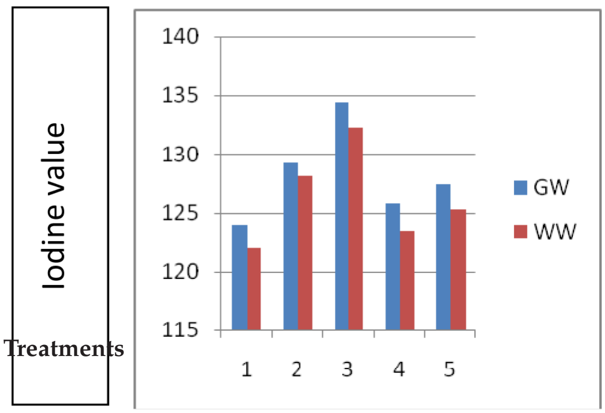


Fig. 10. Effect of ground water (GW) and wastewater (WW) on iodine value of Linseed (*Linum usitatissimum* L.) CV. grown with three levels each of nitrogen, phosphorus and Fly ash

CONCLUSION

It may be concluded that thermal power plant discharged waste products viz; flyash and wastewater can be profitably used for cultivation of linseed as they can prove more efficient in enhancing growth and finally yield. Thus, their application may lower pressure on fertilizer industry and can mitigate the pollution of our already strained water resources and can overcome the economic burden of cash starved farmers of our country.

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