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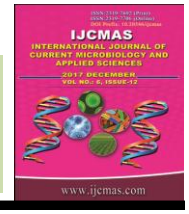

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Effect of Brewery Effluent Irrigation and Sludge Application in Combination with Organic Amendments on Growth and Yield of Sesame (*Sesamum indicum* L.)

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A B S T R A C T

Beer is the world's oldest and most widely consumed alcoholic beverage. The brewing industry is one of the largest users of water, approximately 3 to 10 litres of waste effluent is generated per litre of beer. An investigation was conducted for the utilization of brewery wastewater generated from United Breweries Ltd., situated at Kanjikode, Palakkad District, Kerala state for crop cultivation using different organic amendments. The brewery wastewater was colourless and odourless. The total dissolved solids content was 1320 mg L^{-1}, neutral in reaction (7.05) and the wastewater showed an electrical conductivity of 1.96 dS m^{-1}. The effect of organic amendments under brewery wastewater irrigation on growth of sesame was assessed in field condition. The data of 90 days after sowing (DAS) showed that the brewery wastewater irrigation and the application of different levels of amendments markedly improved the growth of sesame. The yield attributes of sesame (number of capsules per plant, number of seeds per capsule, number of seeds per capsule and test weight) were significantly improved with the addition of amendments in combination with brewery wastewater irrigation. The treatments had significant impact on crop residue and seed yield. The seed yield varied from 433 to 804 kg ha^{-1}. The continuous reuse of brewery wastewater might lead to a salinity buildup, as well as contribute to the deterioration of soil quality. The control application along with the use of organic amendments leads to improve the soil quality as well as the crop yield.

Introduction

Globally there is a great political and social pressure to reduce the pollution arising from industrial activities. Almost all developed and underdeveloped countries are trying to adapt to this reality by modifying their processes, so that their residues can be recycled. The brewing industry is one such industry that generates relatively large amounts of by-products and wastes; spent grain, spent hops and yeast. However, as most of these are agricultural products, they can be readily recycled and reused. Thus compared to other industries, the brewing industry tends to be more environmental friendly (Ishiwaki *et al.*, 2000). A company, which makes beer, is called either a brewery or a brewing company. Beer is the world's oldest and most widely consumed alcoholic beverage and it is produced by the brewing and fermentation of starches, mainly derived from cereal grains -

the most common being malted barley, however wheat, maize / corn and rice are also widely used. The brewing industry is one of the largest users of water. Even though substantial technological improvements have been made in the past, it has been documented that approximately 3 to 10 litres of waste effluent is generated per litre of beer (Genner, 1988 and Manjunatha *et al.,* 2017). In India, there are 64 brewing industries of which 6 are collaboration and the United Breweries Limited (UBL) owns 17. The United Breweries Limited, Palakkad unit discharges wastewater at the rate of 4-5 litres for every litre of beer. Biological treatment is widely applied and two treatment options are available. Generally, aerobic treatment has been applied but recently anaerobic systems have become attractive options. Since it is an oxidative biological reaction, large amounts of biomass are produced, which settle as sludge and requires further disposal. The common disposal route for brewery wastewater sludge has been through landfill. Due to increasing environmental concerns and regulations, attempts were made to utilize the brewery wastes in an eco-friendly manner.

Reuse of wastewater requires careful management to prevent the potential problems such as secondary salinisation. Qadir *et al.*, (2003) indicated the reuse through a plant-based system, which reduced the amount of wastewater requiring further management or disposal. In the agricultural economy of India, oil seeds occupy the second position in terms of hectarage, production and value. Sesame (*Sesamum indicum* L.) is an important ancient oil-yielding crop. Its primary centre of origin is Africa, while India is the secondary centre. Its oil content generally varies from 46 to 52 per cent.

An investigation was conducted for the utilization of brewery wastewater generated from UBL, situated at Kanjikode, Palakkad District, Kerala state for crop cultivation. The crop selected for management of brewery wastewater was fast growth, high salinity tolerance potential for producing commercial products such as food grains and edible oil along with the remediation capability without affecting the food grade. The present study was aimed at examining the short-term effect of brewery wastewater and sludge application on sesame crop growth and yield and evaluating whether the combinations with farm yard manure and vermicompost, and also study the yield and yield parameters of sesame crop.

Materials and Methods

Collection and preservation of brewery wastewater, sludge, farm yard manure, vermicompost, soil and plant sample

The sample of brewery wastewater were collected from United Breweries Ltd., Kanjikode west, Palakkad and analyzed for their physico-chemical and biological properties. Samples for microbiological examinations were collected in clean sterilized bottles. The sampling bottles were closed with glass stopper having an overlapping rim. An intervening strip of paper to prevent breakage of the bottle during sterilization relaxed the stopper. The stopper and neck of the bottles were protected by covering with aluminium foil and sterilized in an autoclave at 20 psi for 15 min. The bottles were opened only at the time of sampling. The samples for the analysis of dissolved oxygen were added with one ml of manganese sulphate solution and one ml of alkaline potassium iodide solution. Samples for the determination of biochemical oxygen demand were preserved by adding five ml of washed chloroform (Chloroform and distilled water were taken in a separating funnel, shaken well and the water layer was discarded) per litre of the sample (APHA, 1980). The water samples were stored at 4^oC in cold room for further analysis.

Sludge, farm yard manure and vermicompost samples were collected during application and were dried under shade, powdered with wooden mallet and sieved through 2 mm sieve and used for further analysis. Initial surface (0-15 cm) soil sample was collected prior to the layout of field experiment to assess the initial status of the experimental soil.

The plant samples collected from the field at the time of harvest were dried and ground in a Willey mill, stored and analysed for various cations and anions. Standard methods were followed for all the sample analysis as per the standard methods.

The physico-chemical characteristics of the wastewater, soil, plant and organic amendments samples were analysed as per the standard methods prescribed by APHA (1998).

Experimental details

The field experiment was conducted at EMPEE breweries, Kanjikode, Palakkad by adopting randomized block design with three replications using brewery wastewater as an irrigation source. Under this experiment, wastewater is used at different dilutions to irrigate. Continuous application of wastewater was done with different dilutions.

A constructed mechanical device was used for the 50 per cent dilution. All the treatment combinations were randomly placed within each replication. The treatment details are described below.

Treatment details (Table 1)

T_1: Control
T_2: Irrigation with brewery wastewater + Recommended Dose of NPK

T_3: Irrigation with brewery wastewater + Vermicompost + Recommended Dose of NPK

T_4: Irrigation with brewery wastewater + Brewery Sludge + Farm Yard Manure + Recommended Dose of NPK

T_5: Irrigation with mixture of brewery wastewater and water (1:1 ratio) + Recommended Dose of NPK

T_6: Irrigation with mixture of brewery wastewater and water (1:1 ratio) + Vermicompost + Recommended Dose of NPK

T_7: Irrigation with mixture of brewery wastewater and water (1:1 ratio) + Brewery Sludge + Farm Yard Manure + Recommended Dose of NPK

(Vermicompost at 3.5 t ha^{-1}, Farm Yard Manure at 12.5 t ha^{-1} and Brewery Sludge at 2 t ha^{-1})

Organic materials used were vermicompost, farm yard manure and brewery industry sludge as per the recommendations.

Results and Discussion

Characteristics of treated brewery wastewater

The treated brewery wastewater collected from the United Breweries Ltd., Kanjikode, Palakkad, analyzed for important physical, chemical and biological properties and are presented in the Table 2. The brewery wastewater was colourless and odourless. The total dissolved solids content was 1320 mg L^{-1}, neutral in reaction (7.05) and the wastewater showed an electrical conductivity of 1.96 dS m^{-1}. This is in line with the findings of Orhue *et al.,* (2005). The brewery wastewater had dissolved oxygen content (DO) of 2.20 mg L^{-1}, biochemical oxygen demand (BOD) of 32 mg L^{-1} and chemical oxygen demand of (COD) of 168 mg L^{-1}. Among the nutrients, the nitrogen (N) and potassium (K) contents were higher, followed by phosphorus (P). Being originated from the plant resources and fermentation process, the brewery wastewater contained considerable amount of plant nutrients. This is in accordance with Orhue *et al.,* (2005) who reported that the brewery wastewater had a BOD of 1000 - 1500 mg L^{-1}, suspended solids of 10 - 60 mg L^{-1}, COD of 800 - 3000 mg L^{-1}, plant nutrients of N and P of 30 - 100 and 10 - 30 mg L^{-1}, respectively and Na content of 212 - 258 mg L^{-1}. Among the cations, sodium (Na) was present in higher amount than Ca and Mg. The sodium content of wastewater was 212 mg L^{-1} with a sodium adsorption ratio of 4.9. Among the micronutrients total iron was maximum (25 mg L^{-1}), followed by total zinc (20 mg L^{-1}), total copper (3 mg L^{-1}) and manganese (2 mg L^{-1}). The heavy metal and oil and grease contents were below detectable level. The microbial population of the brewery wastewater was 10 x 10^6 CFU ml^{-1} for bacteria, 6 x 10^4 CFU ml^{-1} for fungi and 3 x 10^2 CFU ml^{-1} for actinomycetes. The bioassay test indicating the survival rate of fish up to 94 per cent was recorded in brewery wastewater. The total coli forms count was nil.

Initial characteristics of experimental field soil

The soil collected from Kanjikode belongs to Palakkad plains Agro Climatic Zone with a soil type of red loam. The data on initial soil characteristics of the experimental site are presented in Table 3. The experimental soil was clay loam in texture. The soil was neutral (7.40) and non-saline (EC of 0.22 dS m^{-1}). The organic carbon content was medium (0.53 per cent). With regard to nutrient status, the soil was low in N (145 kg ha^{-1}) and P (15.8 kg ha^{-1}) and medium in K (174 kg ha^{-1}) levels. The exchangeable cationic concentrations of Ca, Mg, Na and K were 4.25, 2.36, 0.89 and 0.21 cmol (p^+) kg^{-1}, respectively. The CEC of the soil was 8.19 cmol (p^+) kg^{-1} with an ESP of 11.54. Based on the ESP (>15), EC (< 4 dS m^{-1}) and pH (> 7.40), the soil falls under the classification of sodic soil. It had considerable population of microbes and appreciable level of enzyme activity. Considerable population of microorganisms (bacteria, fungi and actinomycetes) and enzyme (dehydrogenase, phosphatase and urease) activities were also assayed in the experimental field soil used for pot and field experiments.

Characteristics of organic amendments used for field experiments

The chemical constituents of various amendments used for field trials are given in Table 4. The pH of the organic amendments was neutral. Among the organic amendments, ETP sludge recorded an EC of 4.96 dS m^{-1}, followed by vermicompost (1.42 dS m^{-1}) and farm yard manure (1.35 dS m^{-1}). The highest N and P contents were observed in vermicompost (1.68 per cent N and 1.42 per cent P), followed by farm yard manure (0.96 per cent N and 0.80 per cent P). The vermicompost also registered the highest K content of 1.16 per cent followed by ETP sludge (1.12 per cent) and farm yard manure (0.90 per cent). Higher organic carbon content was noticed in farm yard manure (24.20 per cent) followed by vermicompost (22.46 per cent) and ETP sludge (2.08 per cent). The C: N ratio of organic amendments ranged from 25.21:1 to 6.18:1. The amendments also had considerable amount of micronutrients and the brewery sludge recorded the maximum compared to other amendments. The amendments also contained considerable amount of micronutrients. This was in line with the findings of Kanagachandran and Jayaratne (2006); he reported that dry brewery sludge had appreciable quantities of nutrients like N (4.5 %), P (3.3 %), K (0.2 %), Mn (46 mg kg^{-1}), Zn (75 mg kg^{-1}) and Cu (42 mg kg^{-1}).

Growth attributes of sesame under brewery wastewater irrigation

The effect of amendments under brewery wastewater irrigation on growth of sesame was measured in terms of plant height and number of primary branches. The data of 90 days after sowing (DAS) showed that the brewery wastewater irrigation and the application of different levels of amendments markedly improved the growth of sesame (Table 4). In the cropping period, the plant height varied from 81.22 to 115.14 cm at 90 DAS. The number of primary branches ranged from 5 to 7 at 90 DAS. This effect was more pronounced at later stage of plant growth. While plants were shorter in soil with no amendments (T_1) of 81.22 cm, taller on soil that received irrigation with brewery wastewater + vermicompost + RD of NPK (T_3) of 115.14 cm. Application of irrigation with brewery wastewater + vermicompost + RD of NPK (T_3) resulted the tallest plants. The number of primary branches was more in the treatment which received irrigation with mixture of brewery wastewater and water (1:1 ratio) + RD of NPK (T_5) of 7. The rest of the treatments produced average primary number of branches of 6. Among the amendments, application of vermicompost at 3.5 t ha^{-1} + irrigation with brewery wastewater along with RD of NPK, followed by farm yard manure at 12.5 t ha^{-1} + brewery sludge 2 t ha^{-1} along with RD of NPK favoured plant growth parameters. These amendments supply higher quantity of nutrients, organic matter to the soil and increased the uptake of nutrients by plants because of increased availability of major and micronutrients added through brewery sludge and organic manures apart from inorganic fertilizers. Sivasamy (2004) also stated that the number of tillers and number of leaves in cumbu napier hybrid were more in pressmud + algae + 50 per cent GR applied soil under paper mill effluent irrigation. Similar observations were also reported by Parameswari (2009) in garden land crops *viz.*, maize, sunflower and napier grass under saline drainage water irrigation. Crop growth of sunflower increased with increase in dosage of N (Vijaya Kumar *et al.*, 2003).

The poor performance occurred in plots that received irrigation with brewery wastewater along with RD of NPK (T_2), which might be due to poor soil organic matter and more of salinity stress due to continuous brewery wastewater irrigation. Similar results were also reported and the possible explanations for the cause of these effects are, (i) Salinity reduced the carbon translocation from the shoot (ii) It decreased the N uptake (Hawkins and Lewis, 1993) (iii) A higher proportion of the limited supply of root carbohydrates has to be used to generate ATP for osmoregulation and becomes unavailable for nitrate reduction (iv) Salinity inhibits the transport of nitrate from the root to the shoot (Cramer *et al.*, 1995), which is replaced by the transport of amides but at a much lower level, a situation that decreases the amount of organic N available in the shoot for growth. Sumer *et al.*, (2004) found that the reduction of maize growth under saline conditions involves both osmotic and ion effects.

Yield attributes of crops

The yield attributes of sesame (number of capsules per plant, number of seeds per capsule, number of seeds per capsule and test weight) were significantly improved with the addition of amendments in combination with brewery wastewater irrigation. The yield attributes viz., number of capsules per plant, capsule length, number of seeds per capsule, test weight and seed yield per plant in sesame were significantly influenced by the brewery wastewater irrigation and addition of different amendments (Table 5). The number of capsules ranged between 124 and 186. The numbers of seed capsule were increased in treatments of T_2, T_3, T_4 and T_5 over control. The seed capsule length was increased in all the treatments over control. The minimum number of capsules was noticed in T_5 and T_7 of 124 and was on par.

The higher yield attributes were observed under the treatments that received vermicompost than the other organic amendments. Plant biometrics directly correlated to the yield attributes. Addition of farm yard manure at 12.5 t ha^{-1} and brewery sludge at 2 t ha^{-1} might have supplied good amount of organic matter and NPK. The positive impact on the availability of individual plant nutrients, humic substances from organic manures and balanced supplement of nutrients through inorganic fertilizer might have induced the cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency and regulation of water intake into the cells thus resulting in the better yield attributes of crops. These findings are in conformity with the results of Sharma *et al.,* (2002) and Shankaraiah and Kalyanamurthy (2005).

Application of brewery wastewater and amendments had significant effect on number of seeds per capsule. The maximum number of seeds of 55.20 was observed in the treatment that received irrigation with brewery wastewater + vermicompost + RD of NPK (T_3) followed by T_4 (irrigation with brewery wastewater + brewery sludge + farm yard manure + RD of NPK) of 53.28, which was on par with each other and the minimum number was noticed in T_6 (irrigation with mixture of brewery wastewater and water (1:1 ratio) + vermicompost + RD of NPK) of 48.14. All the other treatments were on par with each other. The test weight of the sesame varied from 0.31 to 0.33 g. The data on test weight of sesame indicated that the different dilution of brewery wastewater and amendments were on par with each other. Unlike test weight, the seed yield per plant was increased due to the application of amendments and concentration of brewery wastewater. The seed yield per plant was relatively more (30.8 g) in the treatment which received irrigation with brewery wastewater + vermicompost + RD of NPK (T_3) and was on par with the treatment T_4 (27.6 g).

The tested field crop sesame in the present investigation recorded lower yield attributes in brewery wastewater with RD of NPK. These effects might be due to the salinity through brewery wastewater irrigation which generally inhibited the growth, yield attributes and yield through reduced water absorption, reduced metabolic activities due to Na^+ and Cl^- toxicity and nutrients deficiency caused by ionic interference. These results are in agreement with findings of Mohamedin *et al.,* (2006) and Parameswari (2009).

Yield of crops

The effects of amendments under brewery wastewater irrigation on sesame yield are presented in Table 5. The treatments had significant impact on crop residue and seed yield. The crop residue yield ranged from 3250 to 5267 kg ha^{-1}. While control (T_1) recorded the lowest yield, irrigation with brewery wastewater + vermicompost + RD of NPK (T_3) resulted in the highest crop residue yield (5267 kg ha^{-1}), followed by irrigation with brewery wastewater + vermicompost + RD of NPK (T_2) of 4389 kg ha^{-1}. Lower the growth and yield of barley was recorded by Punith Raj *et al.,* (2017) in treatment receiving irrigation with beverage industry effluent + RDF without gypsum which may be attributed to accumulation of salts. Addition of amendments along with brewery wastewater irrigation significantly improved the stover yield.

Table.1 Details of field experiments

Sl No.	Particulars	Crop III
1.	Soil type	Red loam
2.	Crop	Sesame
3.	Variety	TMV (Sv) 7
4.	Duration	85-90 days
5.	Number of treatments	7
6.	Number of replications	3
7.	Design	RBD
8.	Plot size	5 x 4 m
9.	Spacing	30 × 30 cm
10.	N : P : K (kg ha^{-1})	30 : 15 : 15

Table.2 Characterization of treated brewery industrial wastewater

Parameters	Unit	Values
Physical properties		
Colour	Pt. Co	Colourless
Turbitity	NTU	2
Total suspended solids	mg L^{-1}	1.20
Total dissolved solids	mg L^{-1}	1320
Total solids	mg L^{-1}	1321.20
Physico-chemical properties		
pH	-	7.05
Electrical conductivity	dS m^{-1}	1.96
Dissolved oxygen	mg L^{-1}	2.20
Biochemical oxygen demand	mg L^{-1}	32
Chemical oxygen demand	mg L^{-1}	168
Organic carbon	per cent	BDL
Ammonical nitrogen	mg L^{-1}	4.1
Nitrate nitrogen	mg L^{-1}	45
Total Nitrogen	mg L^{-1}	52
Total Phosphorus	mg L^{-1}	4
Phosphate	mg L^{-1}	5
Carbonate	mg L^{-1}	45
Bicarbonate	mg L^{-1}	68
Total alkalinity	mg L^{-1}	113
Calcium	mg L^{-1}	75
Magnesium	mg L^{-1}	39
Sodium	mg L^{-1}	212
Total Potassium	mg L^{-1}	28
Chloride	mg L^{-1}	335

Parameters	Unit	Values
Sulphate	mg L^{-1}	48
Boron	mg L^{-1}	2
Per cent sodium	-	55
Potential salinity (PS)	meq L^{-1}	9.93
Sodium Adsorption Ratio (SAR)	-	4.9
Residual Sodium Carbonate (RSC)	meq L^{-1}	-1.30
Iron	mg L^{-1}	25
Zinc	mg L^{-1}	20
Copper	mg L^{-1}	3
Manganese	mg L^{-1}	2
Chromium (VI)	mg L^{-1}	BDL
Total chromium	mg L^{-1}	BDL
Cadmium	mg L^{-1}	BDL
Lead	mg L^{-1}	BDL
Nickel	mg L^{-1}	BDL
Mercury	mg L^{-1}	BDL
Oil and grease	mg L^{-1}	BDL
Biological properties		
Bacteria (CFU mL^{-1})	10^6	10
Fungi (CFU mL^{-1})	10^4	6
Actinomycetes (CFU mL^{-1})	10^3	3
Total coli form count	MPN 100 mL^{-1}	BDL
Bio - assay test (survival of fish after 96 h in 100 per cent effluent)	per cent	94

Table.3 Initial characteristics of experimental soil

Parameters	Values
Physico-chemical properties	
pH	7.40
EC (dS m^{-1})	0.22
Organic carbon (per cent)	0.53
Available N (kg ha^{-1})	145
Available P (kg ha^{-1})	15.8
Available K (kg ha^{-1})	174
Exchangeable Ca (cmol (p^+) kg $^{-1}$)	4.25
Exchangeable Mg (cmol (p^+) kg $^{-1}$)	2.36
Exchangeable Na (cmol (p^+) kg $^{-1}$)	0.89
Exchangeable K (cmol (p^+) kg $^{-1}$)	0.21
Biological properties	
Bacteria (x 10^6 CFU g^{-1} of soil)	16
Fungi (x 10^4 CFU g^{-1} of soil)	6
Actinomycetes (x 10^3 CFU g^{-1} of soil)	3
Dehydrogenase (µg of TPF g^{-1} of soil)	5.8
Phosphatase (µg of PNPP g^{-1} of soil)	11.2
Urease (µg NH_4-N g^{-1} of soil h^{-1})	8.8

Table.4 Characteristics of organic amendments

Parameters	Unit	Farm Yard Manure	Vermicompost	Brewery sludge
pH	-	7.35	7.68	7.60
Electrical conductivity	dS m^{-1}	1.35	1.42	4.96
Organic carbon	per cent	24.20	22.46	2.08
Total Nitrogen	per cent	0.96	1.68	0.34
Total Phosphorus	per cent	0.80	1.42	0.65
Total Potassium	per cent	0.90	1.16	1.12
Total Calcium	per cent	1.06	0.68	0.54
Total Magnesium	per cent	0.42	1.42	0.28
C : N ratio	-	25.21	13.37	6.18
Iron	mg kg^{-1}	21.4	12	26.2
Zinc	mg kg^{-1}	10.8	10	19.6
Copper	mg kg^{-1}	146	16	212
Manganese	mg kg^{-1}	45	12	112
Cadmium	mg kg^{-1}	2	1.2	18
Lead	mg kg^{-1}	4.6	2.4	6.5
Nickel	mg kg^{-1}	2.2	1.2	2.2
Chromium	mg kg^{-1}	1.2	0.8	0.6

Table.5 Effect of treated brewery wastewater on the sesame growth, yield and quality parameters

Treatments	Plant height (cm)	Number of primary branches	Number of capsules $plant^{-1}$	Capsule length (cm)	Number of seeds $capsule^{-1}$	Test weight (g)	Seed yield $plant^{-1}$ (g)	Yield parameters		Quality parameters	
								Crop residue (kg ha^{-1})	Seed yield (kg ha^{-1})	Crude protein (per cent)	Oil content (per cent)
T_1	081.22	6	166	2.22	48.20	0.31	21.2	3250	532	13.71	38.23
T_2	106.13	6	181	2.34	50.12	0.33	25.2	4389	610	14.02	40.13
T_3	115.14	6	186	2.47	55.20	0.33	30.8	5267	804	14.23	41.32
T_4	097.10	6	175	2.32	53.28	0.32	27.6	4531	757	13.74	40.62
T_5	102.11	7	124	2.32	50.18	0.32	21.2	3581	433	13.69	40.10
T_6	098.13	5	130	2.30	48.14	0.33	24.2	4250	609	14.12	40.24
T_7	108.14	5	124	2.28	49.18	0.31	21.8	3680	482	13.76	41.00
Mean	**101.14**	**6**	**155**	**2.32**	**50.61**	**0.32**	**24.57**	**4135**	**603**	**13.90**	**40.23**
SEd	**2.28**	**0.13**	**3.40**	**0.05**	**1.12**	**0.007**	**0.56**	**97.28**	**14.4**	**0.31**	**0.90**
CD (0.05)	**4.96**	**0.27**	**7.42**	**0.11**	**2.44**	**0.016**	**1.23**	**211.95**	**31.3**	**NS**	**NS**

Treatments: T_1 - Control; T_2 - Irrigation with brewery wastewater + RD of NPK; T_3 - Irrigation with brewery wastewater + Vermicompost + Recommended Dose of NPK; T_4 - Irrigation with brewery wastewater + Brewery Sludge + Farm Yard Manure + Recommended Dose of NPK; T_5 – Irrigation with mixture of brewery wastewater and water (1:1 ratio) + Recommended Dose of NPK; T_6 - irrigation with brewery wastewater + Vermicompost + Recommended Dose of NPK; T_7 - Irrigation with mixture of brewery wastewater and water (1:1 ratio) + Brewery Sludge + Farm Yard Manure + Recommended Dose of NPK;

Table.6 Effect of treated brewery wastewater on the uptake of ions and nutrients in sesame

Treatments	Cations ($kg\ ha^{-1}$)				Anions ($kg\ ha^{-1}$)	Micronutrients ($g\ ha^{-1}$)				Macronutrients ($kg\ ha^{-1}$)	
	Ca	Mg	Na	K	Cl	Cu	Zn	Fe	Mn	N	P
T_1	18.71	10.14	10.56	9.13	08.76	81	256	410	540	162.3	21.6
T_2	21.62	14.32	16.24	17.22	10.82	87	279	532	549	174.6	21.7
T_3	25.73	16.91	19.49	24.92	14.61	88	301	528	536	179.7	22.4
T_4	28.98	20.64	23.23	28.19	15.93	92	312	567	564	187.6	23.0
T_5	20.43	12.31	17.63	18.27	11.36	82	307	498	539	179.2	20.8
T_6	23.24	19.42	20.12	19.67	13.41	80	324	512	543	186.4	21.9
T_7	24.92	19.56	22.41	22.86	14.89	86	318	522	540	186.3	22.0
Mean	**23.38**	**16.19**	**18.53**	**20.04**	**12.83**	**85**	**300**	**510**	**544**	**179.4**	**21.9**
SEd	**0.54**	**0.41**	**0.46**	**0.50**	**0.31**	**1.87**	**7.00**	**11.63**	**12.23**	**4.11**	**0.49**
CD (0.05)	**1.18**	**0.91**	**1.00**	**1.09**	**0.67**	**4.08**	**15.24**	**25.35**	**NS**	**8.95**	**1.07**

Treatments: T_1 - Control; T_2 - Irrigation with brewery wastewater + RD of NPK; T_3 - Irrigation with brewery wastewater + Vermicompost + Recommended Dose of NPK; T_4 - Irrigation with brewery wastewater + Brewery Sludge + Farm Yard Manure + Recommended Dose of NPK; T_5 - Irrigation with mixture of brewery wastewater and water (1:1 ratio) + Recommended Dose of NPK; T_6 - irrigation with brewery wastewater + Vermicompost + Recommended Dose of NPK; T_7 - Irrigation with mixture of brewery wastewater and water (1:1 ratio) + Brewery Sludge + Farm Yard Manure + Recommended Dose of NPK;

The seed yield varied from 433 to 804 kg ha^{-1}. Similar to crop residue yield, the different levels of amendments application had significant effect on seed yield. The seed yield recorded the highest (804 kg ha^{-1}) in the treatment T_3 (irrigation with brewery wastewater + vermicompost + RD of NPK) followed by T_4 (irrigation with brewery wastewater + farm yard manure + brewery sludge + RD of NPK) of 757 kg ha^{-1}, while the T_5 recorded the lowest yield (433 kg ha^{-1}) which received irrigation with mixture of brewery wastewater and water (1:1 ratio) + RD of NPK.

The yield parameters are the indicators of crop yield. In general, application of amendment significantly increased seed and stalk yield of sesame. This might be due to the favourable effect of organic manures, which enhanced the fertility status of soil and improved the soil physical environment that might have promoted better germination, root proliferation, nutrient and water uptake by the crops (Hati *et al.*, 2007). These results are in conformity with the findings of Pandey (2006).

The seed yield of sesame was higher in the treatment that received vermicompost 3.5 t ha^{-1} + RD of NPK along with irrigation with brewery wastewater. The increase in yield of sesame was 50 per cent over control. Due to the overall significant improvement in yield attributes, crop yield was high in vermicompost followed by farm yard manure and brewery sludge in both the crops. This might be due to slow release of available nutrients throughout the crop growth period and also saline tolerant capacity of the tested crops. The increased yield could be attributed to the presence of essential nutrients in manures and leaching of soluble salts in root zone. Besides the primary nutrients, vermicompost, farm yard manure and brewery sludge also contained secondary nutrients like Ca, Mg, S, trace elements which favored the removal of Na in soil, reduced the ESP and increased the crop growth and yield.

Malarvizhi and Rajamannar (2001) and Parameswari (2009) also reported similar results on maize and sunflower crop.

Quality parameters

The crude protein and oil content of sesame were improved significantly due to brewery wastewater irrigation and the addition of amendments (Table 5). Among the different organic amendments, the irrigation with brewery wastewater + vermicompost + RD of NPK (T_3), recorded the highest crude protein of 14.23 per cent and oil content of 41.32 per cent. The lowest crude protein of 13.71 per cent and oil content of 38.23 per cent was observed in control (T_1) followed by T_2 (Irrigation with brewery wastewater + RD of NPK). The results showed non significance among the various treatments. The addition of amendments substantially increased the quality parameters of crops *viz*., crude protein and oil content of sesame. Similar to yield, amendment application increased the quality parameters significantly.

Among the different amendments, application of vermicompost at 3.5 t ha^{-1} and farm yard manure @ 12.5 t ha^{-1} + brewery sludge @ 2 t ha^{-1} along with brewery wastewater irrigation recorded higher quality parameters in sesame. Addition of amendments along with brewery wastewater irrigation might have provided enough nutrients with better physical and microbial environment, thus improving the soil fertility, which ultimately enhanced crop growth and yield and resulted in improved quality parameters.

This is in agreement with the observations of Parameswari (2009), who reported that the maize, sunflower and cumbu napier grass in drainage water irrigated soil receiving NPK with pressmud or FYM or gypsum as amendment recorded higher values of N, K, crude protein and amino acid content.

Ions uptake

Addition of brewery wastewater and amendments significantly increased the uptake of cations and anions (Table 6). The uptake of cations varied from 18.71 to 28.98, 10.14 to 20.64, 10.56 to 23.23, 9.13 to 28.19 kg ha^{-1} of Ca, Mg, Na and K, respectively, whereas the anion Cl ranged from 8.76 to 15.93 kg ha^{-1}. The maximum uptake of cations and anions were noticed in the treatment T_4 followed by T_3 and was on par and the minimum uptake was observed in control (T_1).

Application of Irrigation with brewery wastewater + brewery sludge + farm yard manure + RD of NPK (T_4) registered the highest N uptake (187.6 kg ha^{-1}) compared to T_1 (162.3 kg ha^{-1}). The result indicated that the brewery wastewater and amendments application significantly increases the plant nitrogen uptake. The P uptake by sesame crop ranged between 20.8 and 23.0 kg ha^{-1}. The P uptake by sesame crop was higher in T_4 (irrigation with brewery wastewater + brewery sludge + farm yard manure + RD of NPK) of 23.0 kg ha^{-1} followed by T_3 (22.4 kg ha^{-1}) and the lowest being registered in T_5 (irrigation with mixture of brewery wastewater and water (1:1 ratio) + RD of NPK) of 20.8 kg ha^{-1}.

The Zn uptake by sesame crop varied between 256 and 324 g ha^{-1} (Table 6). The treatment T_6 registered the highest value of 324 g ha^{-1} followed by T_7 (irrigation with mixture of brewery wastewater and water (1:1 ratio) + farm yard manure + brewery sludge + RD of NPK) of 318 g ha^{-1} and the lowest being recorded in T_1 (control) of 256 g ha^{-1}. The Cu, Fe and Mn uptake by sesame crop ranged from 81 to 92, 410 to 567 and 536 to 564 g ha^{-1}, respectively. The treatment T_4 (irrigation with brewery wastewater + brewery sludge + farm yard manure + RD of NPK) recorded the highest value (92, 567 and 564 g ha^{-1}

respectively). Among the method of application of brewery wastewater and amendments, there was no marked difference in the micronutrients uptake by sesame crop. Significant improvement was observed in the cations (Ca, Mg, Na and K) and anions (Cl) uptake by the sesame crop in amendments applied plots. Such improvements were possibly due to the enhanced biomass of the crop thereby increased the uptake of cations and anions. The minimum uptake of cations and anions were observed in control.

The ion uptake was maximum in the treatment that received farm yard manure @ 12. 5 t ha^{-1} + brewery sludge @ 2 t ha^{-1} with brewery wastewater. The brewery wastewater and amendments treated plots received carbon sources and other nutrients that promoted greater microbial and enzyme activities in soil which in turn facilitated higher rate of mineralization leading to addition of nutrients to soil. The amendment application, because of its organic matter content, might have improved the soil physical conditions, favouring better root and shoot growth and nutrients uptake. In the present study, both the crops exhibited maximum uptake of cations than anions. The results on cations and anions uptake by crops are in agreement with the findings of De Lacerda *et al.*, (2003). It was reported that Na^+ uptake increased and K^+ uptake decreased in plants and high levels of Na^+ inhibited the K^+ concentration in sunflower plants and as a result it caused an increase in the Na^+/K^+ ratio.

Based on the above results from field trials, it could be concluded that, the sesame crop performed well under brewery wastewater irrigation along with different amendments. The continuous reuse of brewery wastewater might lead to a salinity buildup, as well as contribute to the deterioration of soil quality. But in Palakkad region due to the even distribution of rain with high intensity, one season of crop might be under rainfed condition which might dilute the pollutants and be utilized during the next cropping season. This problem could be effectively managed by the use of soil amendments (farm yard manure at 12.5 t ha^{-1} and vermicompost along with 100 per cent brewery wastewater and NPK).

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