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RESPONSE OF MAIZE TO BREWERY WASTEWATER IRRIGATION AND ITS EFFECT ON SUBSEQUENT PADDY YIELD AND SOIL QUALITY

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ABSTRACT
Majority of the industries in India are agro-based and utilize large volume of fresh water and turn almost this entire quantity of water in to an effluent. The brewing industry is one of the largest users of water. Field experiments was conducted at United Breweries Limited, Nelamangala and Zonal Agricultural Research Station, Bengaluru, Karnataka, India in sandy loam soil results revealed that application of 150% Recommended dose of nitrogen through treated brewery wastewater as 50% basal and 50% in three irrigations recorded significantly higher growth, yield parameters, grain yield (39.6 q/ha) and stover yield (69.9 q/ha) of maize compared to all other treatments. However, residual and cumulative effect of same treatment recorded significantly higher grain yield (21.3 & 43.8 q/ha, respectively) and straw (26.8 & 52.4 q/ha, respectively) yield of paddy compared to fresh water along with recommended dose of fertilizers. Similar treatment recorded significantly higher fungi, bacteria and actinomycetes population (45.46 & 53.43 cfu x10^5, 28.39 & 39.24 cfu x10^4 and 24.56 & 29.98 cfu x10^3, residual and cumulative respectively) compared to freshwater along with RDF. Increasing application treated brewery wastewater resulted increasing the yield and soil quality.

INTRODUCTION

Currently, agriculture accounts for more than 80% of India's water use. But growing demand from other uses such as municipal and industrial, is leading to increased competition among uses, especially near urban areas. The 2050 projections show aggregate water demand increasing to 1,447 km^3 while agriculture retains its relative dominance, other uses are projected to increase their relative share (Abhijit Banerjee, 2010). Water and nutrients are the most important factors for crop production and their management is more challenging due to their scarcity and high cost. Their efficient use is indispensable for sustainable agriculture in view of the shrinking land, man and water, man ratios, increasing fertilizer prices, haunting energy crisis, wide spread pollution and fast degradation and depletion of natural resources. Therefore, precision agriculture in India is necessitated to produce about 350 million tonnes of food grains by 2020 to feed the ever growing population.

Pollution of soil and water bodies is a serious problem ever since man started disposing sewage and industrial effluents into water bodies and on land. Majority of the industries in India are agro-based and utilize large volume of fresh water and turn almost this entire quantity of water in to an effluent. Wastewater is frequently preferred due to its high nutrient value, in some cases even over freshwater as in Gandhinagar and Rajkot in Gujarat. Farmers are sometimes willing to pay a price premium for wastewater due to this perceived benefit (Palrecha *et al.*, 2012).

The brewing industry is one such industry that generates relatively large amounts of by-products and wastes such as 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). The problem of pollution was accentuated due to rapid industrialization and spurt in human population. The brewing industry is one of the largest industrial 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 produced in breweries as much of the excess water has to be heated in the brewing and cleaning processes. Beer factory sludge increased leaf and root yield, the highest sugar content, refined sugar content and refined sugar yield were obtained with the application rate of 10 tonnes beer factory sludge per hectare. Ten tonnes of beer factory sludge per hectare was the most suitable on the basis of root quality parameters and root yield (Cihat Kutuk *et al.*, 2003). Application of 0, 25, 50, 75 and 100 % brewery effluent decreased the organic carbon, N, P, Na, and Mg concentration in the soil while K, Ca, C/N ratio, soil pH were increased. There were no changes observed in the soil textural class. The growth of maize plant as well as chlorophyll content was enhanced with brewery effluent treatments when compared with the control (Orhue *et al*., 2005). Combined use of brewery wastewater sludge and two different types of composts increased the germination per cent and dry matter yield of chili and pumpkin when compared to brewery wastewater sludge or compost alone. Brewery wastewater sludge has recorded higher water retention capacity when compared to compost (Kangachandran and Jayaratne, 2006). The unscientific disposal of this wastewater on soil and in to water bodies may create serious problems of pollution. With the growing realization that chemical based agriculture is unsuitable and is slowly leading to ecological imbalance (Vijaya tartte and Chandra mouli kalla, 2010)

Hence, present study is attempted to explore the potentiality of brewery wastewater utilization in agriculture especially on growth and yield brewable crops.

MATERIALS AND METHODS

An attempt was made to solve the problem of industrial disposal and water scarcity to crops. Field experiments were conducted at United Breweries (UB) Ltd., Nelamangala and Zonal Agricultural Research Station, UAS, GKVK, Bengaluru located in Eastern dry zone of Karnataka and situated at 12° 11' North latitude 76° 69' East longitude with an altitude of 980 meters above mean sea level during 2009 and 2010. The soils of the experimental site at UB Ltd, Nelamangala was sandy loam in texture and soil was neutral in reaction (pH 7.19). Electrical conductivity of soil was 0.18 dS/m. The organic carbon content was 0.58 per cent. The available nitrogen was medium (315.8 kg/ha), phosphorus was low (13.17 kg/ha) and potassium (103.4 kg/ha) was low. At ZARS, GKVK, the soil was sandy clay loam in texture, acidic in reaction (pH 6.4) and electrical conductivity of 0.15 dSm^{-1}. The organic carbon content was 0.56 per cent. The available nitrogen was low (221.34 kg/ha), phosphorus was low (19.13 kg/ha) and potassium (265.25 kg/ha) was medium. The experiments were laid out in randomized complete block design (RCBD) consisting of nine treatments and replicated thrice. The hybrid Maize (NAH-2049) and variety Mangala (paddy) is used as test crop.

The treatment details and corresponding symbol used in the study are as follows T_1: fresh water + RDF, T_2: RDN through UBWW as 50 % basal and 50 % in three irrigations, T_3: RDN through UBWW as 25 % basal and 75 % in three irrigations, T_4: RDN through TBWW as 50 % basal and 50 % in three irrigations, T_5: RDN through TBWW as 25 % basal and 75 % in three irrigations, T_6: 150% RDN through UBWW as 50 % basal and 50 % in three irrigations, T_7: 150% RDN through UBWW as 25 % basal and 75 % in three irrigations, T_8: 150% RDN through TBWW as 50 % basal and 50 % in three irrigations, T_9: 150% RDN through TBWW as 25 % basal and 75 % in three irrigations. Residual and cumulative effect of above said treatments were studied on subsequent paddy crop. The experimental results were statistically scrutinized as suggested by Panse and Sukhatme (1985). The critical difference was worked out at 5 per cent (0.05) probability levels.

Abbre. RDF- Recommended dose of fertilizers, RDN- Recommended dose of nitrogen, UBWW- Untreated brewery wastewater, TBWW- Treated brewery wastewater,

RESULTS AND DISCUSSION

Many factors both externally and internally influence the crop growth and productivity. Nutrient management is one such important factor which largely decides the yield of the crop produced. The economic yield of a plant is an outcome of a series of integrated interactions of various biological events involving biochemical, physiological and morphological changes those occur during its development in accordance with the supply of light, water, temperature and nutrients (Donald, 1962).

The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depends upon efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. The production and translocation of synthesized photosynthates depends upon mineral nutrition supplied either by soil or through foliar application. Most of the photosynthetic pathways are dependent on enzymes and co-enzymes which are synthesized from mineral elements such as nitrogen, phosphorus and potassium.

Nitrogen improves plant growth and productivity by having direct effect on the metabolism of plants. Nitrogen is usually applied through organic or inorganic sources. Cereals consume more amount of nitrogen when compared to other major nutrients, as it is essential in almost all the metabolic processes. The time of application as well as the stage of plant growth determines the uptake and translocation of nitrogen. Phosphorus and potassium supply in early vegetative stage has greater influence on yield of crops. Hence, major nutrients play a vital role in growth, yield and quality of crops.

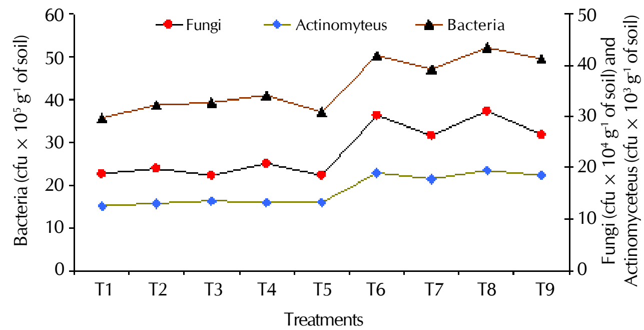
In field experiments involving maize-paddy sequence, crop yields, growth and yield parameters of the crops differed slightly during first (2009) and second (2010) year of experiments, but the pattern of response to brewery wastewater used for irrigation was similar in both the years. Therefore, only pooled data of the two years are presented.

The data on grain yield of maize differed significantly due to brewery wastewater irrigation (Table 1). Significantly higher grain yield was observed with 150% recommended N through TBWW as 50% basal and 50% in three irrigations (T_8: 39.6 q/ha) which was superior over all other treatments but it was on par with T_6 (39.1 q/ha), T_9 (38.2 q/ha) and T_7 (37.8 q/ha). However, in treated brewery wastewater irrigation with recommended N through TBWW as 50% basal and 50% in three irrigations (T_4: 32.5 q/ha) recorded higher grain yield and it was at par with T_2 (32.3 q/ha), T_5 (31.2 q/ha) and T_3 (30.2 q/ha). While, significantly lower grain yield (30.5 q/ha) was recorded in plots which receive fresh water + RDF (T_1). Application of 150% recommended N through TBWW as 50% basal and 50% in three irrigations recorded significantly higher stover yield (T_8: 69.9 q/ha) which was superior over all other treatments but it was on par with T_6 (69.2 q/ha), T_9 (67.6 q/ha) and T_7 (66.3 q/ha). Increase in grain and stover yield of

Table 1: Brewery wastewater irrigation on maize yield and its residual, cumulative effect on paddy grain and straw yields in maize-paddy sequence

Treatments	Maize Direct application Grain yield (q/ha) 2009	2010	Pooled	Stover yield (q/ha) 2009	2010	Pooled	Paddy Residual Grain yield (q/ha) 2009	2010	Pooled	Straw yield (q/ha) 2009	2010	Pooled	Cumulative Grain yield (q/ha) 2009	2010	Pooled	Straw yield (q/ha) 2009	2010	Pooled
T_1	27.0	33.9	30.5	45.8	56.1	51.0	12.7	15.9	14.3	17.5	19.4	18.5	26.1	26.7	26.4	28.6	27.5	28.1
T_2	30.2	34.4	32.3	48.7	58.4	53.5	15.1	18.0	16.6	19.0	21.2	20.1	33.0	32.9	32.9	36.3	39.9	38.1
T_3	27.6	33.7	30.7	46.9	57.3	52.1	15.1	17.1	16.7	18.4	19.9	19.2	32.0	31.9	31.9	35.2	37.1	36.1
T_4	30.4	34.6	32.5	51.7	58.6	55.2	15.2	18.1	16.7	19.5	22.3	20.9	33.9	33.8	33.8	37.2	40.9	39.1
T_5	28.6	33.7	31.2	50.8	58.3	54.6	15.1	17.7	16.4	18.9	20.7	19.8	32.6	32.5	32.5	35.8	39.1	37.1
T_6	35.7	42.5	39.1	64.5	73.9	69.2	18.6	23.6	21.1	24.6	28.3	26.5	43.5	43.4	43.5	49.9	52.8	51.3
T_7	35.0	40.6	37.8	61.4	71.2	66.3	18.2	22.4	20.3	22.7	26.4	24.6	42.7	42.6	42.7	48.9	51.5	50.2
T_8	36.7	42.6	39.6	65.1	74.6	69.9	18.9	23.6	21.3	25.2	28.5	26.8	43.9	43.8	43.8	50.3	54.4	52.4
T_9	35.5	40.9	38.2	63.3	71.9	67.6	18.4	23.0	20.7	23.6	27.4	25.5	43.3	43.2	43.3	49.0	52.7	50.9
S. Em ±	1.01	1.97	1.54	2.02	3.44	3.00	0.93	1.19	1.06	0.69	1.25	0.99	2.66	2.67	2.58	3.03	3.17	3.02
C. D. at 5%	3.05	5.92	4.43	6.07	10.30	8.63	2.29	3.57	3.01	2.09	3.75	2.86	7.97	8.01	7.43	9.07	9.51	8.67

Note:
T_1 - Fresh water + RDF; T_2 -RDN through UBWW as 50 % basal and 50 % in three irrigations; T_3 -RDN through UBWW as 25 % basal and 75 % in three irrigations; T_4 - RDN through TBWW as 50 % basal and 50 % in three irrigations; T_5 -RDN through TBWW as 25 % basal and 75 % in three irrigations; T_6 -150 % RDN through UBWW as 50 % basal and 50 % in three irrigations ; T_7 -150 % RDN through UBWW as 25 % basal and 75 % in three irrigations; T_8 -150 % RDN through TBWW as 50 % basal and 50 % in three irrigations; T_9 -150 % RDN through TBWW as 25 % basal and 75 % in three irrigations; UBWW- Untreated Brewery Wastewater, TBWW- Treated Brewery Wastewater; Recommended dose of fertilizer: Maize-150:75:40 kg N, P_2O_5 and K_2O ha-1, Paddy-100:50:50 kg N, P_2O_5 and K_2O ha^{-1} for T_1 cumulative and FYM: 10 t ha^{-1} common for all the cumulative treatments



Legend

T_1: Fresh water + RDF; T_2: Rec. N through UBWW as 50 % basal and 50 % in three irrigations; T_3: Rec. N through UBWW as 25 % basal and 75 % in three irrigations; T_4: Rec. N through TBWW as 50 % basal and 50 % in three irrigations; T_5: Rec. N through TBWW as 25 % basal and 75 % in three irrigations; T_6: 150 % Rec. N through UBWW as 50 % basal and 50 % in three irrigations; T_7: 150 % Rec. N through UBWW as 25 % basal and 75 % in three irrigations; T_8: 150 % Rec. N through TBWW as 50 % basal and 50 % in three irrigations; T_9: 150 % Rec. N through TBWW as 25 % basal and 75 % in three irrigations

Figure 1: Soil microbial population as influenced by brewery wastewater irrigation on maize

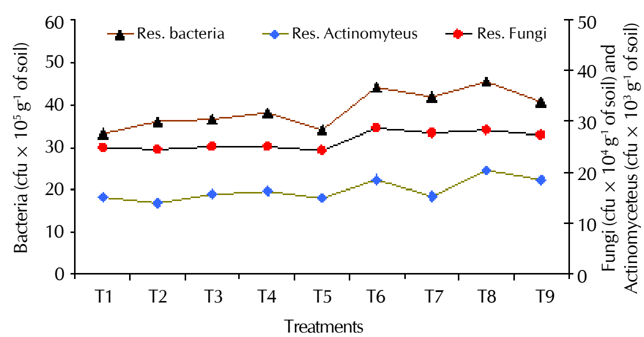


Figure 2: Soil microbial population as influenced by residual effect of brewery wastewater irrigation in paddy

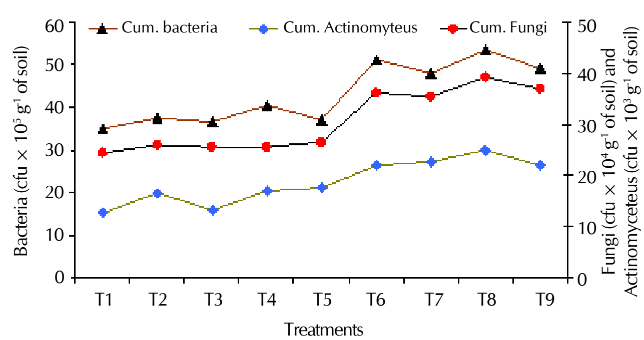


Figure 3: Soil microbial population as influenced by cumulative effect of brewery wastewater irrigation in paddy

maize is due to higher plant height, more number of leaves, leaf area, leaf area index, total dry matter accumulation, number of cobs $plant^{-1}$, more cob length, number of rows cob^{-1} and test weight observed in this treatments. These results are in conformity with the findings of Efstathios *et al*. (2009) revealed that treated urban wastewater effectively increased the yield of cultivated forage crop species due to the nutritive value of the wastewater, although the differences were not statistically significant. Field experiments at Nigeria agricultural farm during 2006 and 2007 results revealed that application of palm oil mill effluent in maize as organic fertilizer increased dry matter, grain yield, stover yield and grain NPK content (Nwoko, 2010) and Selim (2008) reported that crops irrigated with secondary treated wastewater performed equally well or significantly better than those irrigated with canal water. Seed and biological yields of plants given wastewater in the absence of chemical fertilizers were nearly equal to those of plants given the recommended dose of chemical fertilizers, indicating that wastewater could provide an adequate amount of N, P and K to cover crop requirements at different growth stages. Senthilraja *et al.* (2013) revealed that brewery wastewater application produced significantly more dry matter than the other treatments in Maize, Sunflower and Sesame crops. The higher concentration of brewery wastewater irrigation significantly increases the dry matter production such effect was more pronounced in maize.

Changes in soil biological activity (population of microbial) influenced by brewery wastewater irrigation in maize-paddy sequence

After harvest of maize crop soil samples were analyzed for soil microbial population like fungi, bacteria & actinomycetes and results presented below

The soil beneficial microorganisms such as soil fungi, bacteria, actinomycetes, N-fixers and P-solublizer populations differed significantly due to application of brewery wastewater irrigation in maize- paddy sequence (Fig 1-3).

After harvest of maize soil samples were used for microbial count by using standard procedures separately for Fungi, Bacteria and Actinomycetes. Significantly higher bacterial population (52.19 cfu x 10^5) was observed with 150% recommended N through TBWW as 50% basal and 50% in three irrigations (T_8) compared to all other treatments but it was on par with T_6 (50.51 cfu x 10^5), T_9 (49.53 cfu x 10^5) and T_7 (47.19 cfu x 10^5). Significantly lower bacterial population (35.80 cfu x 10^5) was observed with fresh waster + RDF (T_1). Similar trend was observed in fungi and actinomycetes population. Similar findings were reported by Rajkishore and Vignesh (2012) that distillery effluent being rich in nutrients and organic matter was found to improve the soil microbial populations.

In case of paddy similar trend was noticed with residual and cumulative effect brewery wastewater irrigation. Treatment receiving 150% RDN through TBWW as 50% basal and 50% in three irrigations recorded significantly higher fungi, bacteria and actinomycetes population (45.46 & 53.43 cfu x10^5, 28.39 & 39.24 cfu x10^4 and 24.56 & 29.98 cfu x10^3, residual and cumulative respectively) compared to freshwater along with RDF. The findings are in conformity with the results of Shang Ran (2003) observed that increasing the ratio of wastewater concentration continuously increasing the quantities of bacteria, actionomycetes, aerobic cellulose-decomposing bacteria, nitric acid bacteria, nitrous acid bacteria, free-living nitrogen-fixing bacteria and decreasing later. At higher wastewater concentration the nutrient components in sewage could stimulate fungus, nitrifying bacteria, denitrifying bacteria and some anaerobic bacteria to propagate. Irrigation concentration of brewery wastewater sludge with the optimum ratio of water to sewage of i.e. 2:1 or 1:2 found best and the higher sewage concentration would be disadvantageous to plant growth and Jnaneesh (2008) who reported that soil fungi, bacterial and actinomycetes population were increased due to application of coffee pulp effluent. Ekhaise and Anyasi (2005) were analyzed brewery wastewater for total microbial population, which had values ranging from 1.0 x 10^3 to 4.8x10^3 cfu ml^{-1} and 1.3x10^7 to 5.7x10^7 cfu ml^{-1} for the fungal and bacterial isolates respectively. Total coli-form counts ranged from 4.3x10 MPN/100 ml to 38x10 MPN/100ml. Microorganisms isolated include *Sacchromyces cereviceae*, *Aspergillus niger*, *Penicillium* sp., *Geotrichum* sp. *Candida* sp., *Proteus* sp. *Staphylococcus* sp, *Escherichia coli*, *Streptococcus faecalis* and *Bacillus* sp.

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