UTILIZATION OF SPENT WASH THROUGH BIO-COMPOST FOR *SURU* SUGARCANE UNDER NORMAL AND SODIC SOIL CONDITION

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI - 413722, DIST. AHMEDNAGAR,
MAHARASHTRA, INDIA

in partial fulfilment of the requirements for the degree of

DOCTOR OF PHILOSOPHY (AGRICULTURE)
in

AGRICULTURAL CHEMISTRY
by

Mahavirsing Ramcharan Chauhan
(Reg.No. 05/013)

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

POST GRADUATE INSTITUTE
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2013

CANDIDATE'S DECLARATION

I hereby declared that, this thesis entitles "Utilization of spent wash through bio-compost for suru sugarcan under normal and sodic soil conditions" or any part there of has not been previously submitted by me or any other person for a degree or diploma of any other University or Institute.

Place: MPKV Rahuri ***Mahavirsing R.Chauhan***

Date : 30/05/2012

Dr. A.L. Pharande
Professor and Head
Deptt.of Soil Science
And Agricultural Chemistry,
Maharashtra State (INDIA)

CERTIFICATE

This is to certify that, the thesis entitled, "**UTILIZATION OF SPENT WASH THROUGH BIO-COMPOST FOR *SURU* SUGARCANE UNDER NORMAL AND SODIC SOIL CONDITION",**submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra for the award of the degree of **DOCTOR OF PHILOSOPHY(AGRICULTURE)** in **ARICULTURAL CHEMISTRY**, embodies the results of a *bonafide* research carried out by **MR.MAHAVIRSING RAMCHARAN CHAUHAN,**under my guidance and supervision and that no part of the thesis has been submitted for any other Degree or Publication.

The assistance and help received during the course of this investigations and sources of literature referred to have been duly acknowledged.

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(A.L. Pharande)

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CERTIFICATE

This is to certify that,the thesis entitled, "**UTILIZATION OF SPENT WASH THROUGH BIO-COMPOST FOR *SURU* SUGARCANE UNDER NORMAL AND SODIC SOIL CONDITION",** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **AGRICULTURAL CHEMISTRY**, embodies the results of a *bonafide* research carried out by **MR.MAHAVIRSING RAMCHARAN CHAUHAN,** under the guidance and supervision of **Dr. A.L. Pharande,** Professor and Head Department of Soil Science and Agricultural Chemistry ,M.P.K.V. Rahuri and that no part of the thesis has been submitted for any other Degree or Publication.

Place : MPKV, Rahuri **(S.G.Borkar)**
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Place : M.P.K.V., Rahuri

Date : / /2013 **(Mahavirsing R. Chauhan)**

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LIST OF ABBREVIATIONS

AC	Absolute Control
RSW	Raw Spent Wash
PBSW	Post Bio-methanated Spent Wash
BC	Baggasse Compost
STC	Sugarcane Trash Compost
PMC	Press Mud Cake
WSC	Wheat Straw Compost
PeBWC	Pearl Millet Byre Waste Compost
CSC	Chickpea Straw Compost
FYM	Farm Yard Manure
VC	Vermicompost
RDF	Recommended Dose of Fertilizer
AST	As Per Soil Test
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
@	At the Rate
NH_4-N	Ammonical nitrogen
NO_3-N	Nitrate nitrogen
C	Carbon
CEC	Cation Exchange Capacity
Cm hr^{-1}	Centimeter per hour
C.D.	Critical Differences
CFU g^{-1}	Colony forming unit per gram
m^{-3}	Cubic meter
dS m^{-1}	Deci siemens per meter
^{0}C	Degree Celcius
EC	Electrical Conductivity
ESP	Exchangeable Sodium Percentage

EMP	Exchangeable Magnesium Percentage
Fig.	Figure
g	gram
ha	Hectare
hrs	Hours
kg ha^{-1}	Kilogram per hectare
Max.	Maximum
Min.	Minimum
GL	Gegga Litre
L	Litre
SAR	Sodium Adsorption Ratio
me L^{-1}	Milliequivalent per Litre
Mg m^{-3}	Mega gram per cubic meter
Mg ha^{-1}	Mega gram per hectare
mm	Milimeter
mg kg^{-1}	Milligram per kilogram
MOP	Muriate of Potash
viz.,	Namely (videlicent)
N	Nitrogen
S.E.	Standard Error
t ha^{-1}	Tonnes per hectare
i.e.	That is (id est.)

ABSTRACT

UTILIZATION OF SPENT WASH THROUGH BIO-COMPOST FOR *SURU* SUGARCANE UNDER NORMAL AND SODIC SOIL CONDITION

By

Shri. Mahavirsing Ramcharan Chauhan

A candidate for the degree

of

DOCTOR OF PHYLOSOPHY (AGRICULTURE)

In AGRICULTURAL CHEMISTRY

2013

Research Guide : Dr. A.L. Pharande

Department : Soil Science and Agricultural Chemistry

The field trial was conducted on the farm of Post Graduate Institute, Department of Soil Science and Agril. Chemistry, MPKV, Rahuri, Dist. Ahmednagar (M.S.) during the year 2007-08 on *Suru* (Seasonal) Sugarcane (cv. CO 86032) with sixteen treatments and three replications. Randomized block design was used for statistical study.The spent wash bio-composts were used for sugarcane crop as manure.

The bio-compost was prepared on the site of Kolpewadi Co-operative Sugar Factory Ltd., Kopargaon Dist. Ahmednagar (M.S.). One ton each of six different crop residues/organic sources *viz*., baggasse, sugarcane trash, press mud cake, wheat cut straw, pearl millet straw, chick pea straw with three tonnes of raw and post bio-methanated spent wash were used by aerobic method of decomposition (Heap method) for preparation of bio-composts.

Decomposing culture was used with timely mixing and turning. The bio-compost of 150 days was used for sugarcane crop prior to one month before planting of sugarcane. The NPK fertilizers were applied through urea, single super phosphate and muriate of potash on the basis of available soil test whereas different bio-compost and manures were applied on the basis of nitrogen content.

The crop residues were characterized and their results indicated that the highest C: N ratio (125:1) was reported in sugarcane trash followed by pearl millet straw (120:1) and baggasse (80.4:1), however, the chickpea straw showed the lowest C: N ratio (40:1) with higher nitrogen content (0.90 %). Higher phosphorous content was noticed in press mud cake (1.30 %) whereas pearl millet straw showed the highest total K content (1.30 %). The PMC showed the higher Fe (3308 mg kg^{-1}), Zn (251 mg kg^{-1}) and Cu (110 mg kg^{-1}) content as compared to rest of the crop residues.

The chemical properties indicated that, raw spent wash was acidic in nature (pH 4.2) with dark coffee brown colour, unpleasant odour, very high content of soluble salts (19.85 dSm^{-1}), high BOD (32000 mg L^{-1}) and COD (91000 mg L^{-1}) content.

The total NPK content was 1100, 30.85 and 8800 mg L^{-1}, respectively. The post bio-methanated spent wash was neutral to slightly alkaline (pH 7.2) in reaction, dark redish in colour with unpleasant odour. The EC was moderate (12.55 dSm^{-1}) with lower content of BOD (4400 mgL^{-1}) and COD (25000 mg L^{-1}) as compared to raw spent wash. The total NPK content was 850, 10.25 and 6000 mg L^{-1}, respectively.

In the characterization study of bio-composts the pH at 30 days was slightly acidic, which was slightly increased to neutral at 120 days of period of decomposition of bio-composts. The use of raw spent wash showed comparatively lower values of pH than post bio-methanated spent wash compost of their respective crop residues. The electrical conductivity of bio-composts was also steadily increased from 30, 60, 90 and 120 days. The organic ‘C’ content steadily declined from 30 days to 120 days in all the bio-composts during decomposition. As maturity of compost increases from 30 to 120 days the content of N, P, K and S was steadily increased with stage of maturity. The C:N and C:S ratio of all the bio-composts prepared from crop residues were continuously declined at 30, 60, 90 and 120 days of decomposition. The press mud compost showed comparatively the lowest C:P ratio than other crop residues. At 120 days of decomposition stage the fulvic acid content showed increasing trend than humic acid. Among the different bio-composts prepared from spent wash the application of post bio-methanated spent wash showed significant improvement in tillering ratio, millable cane, cane yield and top yield, CCS yield, NPK and micronutrient uptake not only in normal soil but also in sodic soil followed by post bio-methanated spent wash + chickpea straw bio-compost.

The soil physical, chemical and biological properties after harvest of *suru* sugarcane as well as NH_4 and NO_3–N release under incubation study was significantly improved due to application of bio-compost, specially post bio-methanated spent wash + press mud cake and post bio-methanated spent wash + chick pea straw for sodic as well as normal soil over control and RDF.

Abstract contd... **Shri. M.R. Chauhan**

The study indicated that the post bio-methanated spent wash could be utilized for preparation of bio-composts specifically from press mud cake and chickpea straw as compared to raw spent wash due to its neutral pH, low salt load, and higher content of organic carbon, low biological oxygen demand and chemical oxygen demand with higher content of macro and micro nutrients.

The utilization of post bio-methanated spent wash+ press mud cake(3:1) bio-composts (12.39 t ha^{-1}) as well as post bio-methanated spent wash+ chick pea straw((3:1) bio-composts (17.28 t ha^{-1}) for *suru* sugarcane under sodic as well as normal vertisol could enhance the soil physical, chemical and biological properties with significant improvement in cane yield, juice quality and nutrient uptake.

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1. INTRODUCTION

Distillery is one of the most important agro-based industries in India for manufacturing of alcohol from molasses. Spent wash very foul smelling dark coffee coloured waste water, which is the principal residue from alcohol industry, possess major problem in disposal (Alam *et al.,* 2008).

Maharashtra state has a very congenial climate for the sugarcane production among the cane growing states of India. The area under sugarcane crop in Maharashtra is 3.83 lakhs ha with the total cane production of 34.0 thousand metric tonnes. There are 96 sugar factories crushing the sugarcane and sugar production is to the extent of 3.9 thousand metric tonnes with an average recovery of 10.71 per cent (Anonymous, 2009).

In India, 285 distilleries are presently operating which produce about 2.75 billion liters (giga) (GL) of alcohol and 30.45 GL of spent wash as a by-product per year (Anonymous, 2007). In Maharashtra, the amount of spent wash could be estimated as 9367 million litres per year from 725 million litres (Installed capacity) of alcohol production from 72 distilleries (Anonymous, 2006). Sugarcane crop and the sugar industries are playing vital role in socio-economical structure of India. Sugarcane (*Saccharum officinarum*) has world wide significance as a major source of food (sugar) and large amount of by-products which are economically more viable.

Sugarcane based industries playing pivotal role in promoting alcohol, paper and other by-product industries in the country. Among them, press mud, baggasse, sugarcane trash, molasses and boiler ash are the important by-products. It plays key role in contributing to the rural agro- industrial development of India in general and Maharashtra in particular with rapid growth of sugar industries. The press mud and molasses by-products are obtained in huge quantities. Manufacturing of alcohol from sugarcane molasses which is very important by-product of sugarcane industry.Around 246 distilleries have about 2215 million litres potential production of alcohol per annum in India. The quantity of spent wash produced is 12-15 times more than that of alcohol produced i.e. 33,225 million litres per year (Manohar Rao, 1983). During recent years; India has emerged as a largest sugarcane producer in the world. In sugar factories huge quantity of molasses is being produced as end product, which is used in distilleries for alcohol production.In India, about 303 distilleries are operating with production of 6542 thousand tonnes of molasses per year. In Maharashtra, it is estimated as 30.47 lakh metric tonnes per year (Anonymous, 2010).

In the distilleries, molasses are fermented with the help of yeast (*Saccharomyces cerevisiae*). The fermented wash is distilled and alcohol is obtained. The liquid which is left after distillation is known as spent wash. This spent wash is recycled, from which methane is obtained. The methane gas is used as a source of energy and has potentiality to generate electricity and also for saving valuable baggasse which can be alternatively used for paper making and other purposes. Therefore, most of the factories/distilleries have adopted methane generation technology.

Molasses (one of the important by-product of sugar industry) is the chief source for production of alcohol in distilleries by fermentation method. About 40 billion litres of waste water annually discharged in distilleries known as raw spent wash (RSW), which is characterized by high biological oxygen demand and chemical oxygen demand, which has been undesirable colour and foul smell. Discharge of raw spent wash in open land or near by water bodies resulting in air, water and soil pollution including threat to plant and animal lives. Hence, discharge of spent wash is very serious problem. The RSW is highly acidic and contains easily oxidisable organic matter with very high biological oxygen demand and chemical oxygen demand (Patil *et al.* 1987). Spent wash contains significant quantities of plant nutrients. The process of generation of post bio-methanated spent wash can reduce biological oxygen demand and chemical oxygen demand than raw spent wash. It is also called as primary treated spent wash (PTSW) and primary treatment to raw spent wash increases the nitrogen (N), potassium (K) and phosphorous (P) contents and decreases the calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), chlorides (Cl^{-}) and sulphates (SO_4^{2-}) (Haroon and Bose, 2004). The PTSW is rich in potassium, sulphur, nitrogen, phosphorus as well as easy bio-degradable organic matter and its application to soil has been reported to be beneficial to increase the crop yield and quality of sugarcane, rice, wheat, groundnut and soybean. Therefore, PTSW is very good source as a nutrient for field crops.

The large quantities of spent wash is being generated from distilleries, poses a problem of disposal. It has a high salt load with higher biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values ranged from 40,000 to 60,000 and 80,000 to 1,20,000 mg L^{-1}, respectively. This leads to risk of environmental pollution. If, it is disposed in water sources, without proper treatment it will pose a serious threat to aquatic life, due to depletion of dissolved oxygen. In soil, the accumulation of toxic salts, lowering of pH and alkalinity occurs with the use of spent wash. Due to release of gases like ammonia, nitrous oxide, hydrogen sulphide, methane, carbon-dioxide etc. it has an unpleasant smell. The major challenges for the distilleries are it's management and safe disposal of enormous volume of spent wash generated. The technology proposed by Central Pollution Control Board (CPCB) for disposal of distillery effluents involves anaerobic dilution of distillery spent wash for methane generation (bio-methanation) is proved to be the best alternative process.

The spent wash is one of the strongest industrial wastes, polluting environment and ground water. Therefore, most severe problem faced by sugarcane distilleries are the disposal of huge quantity of spent wash without causing pollution of environment and looking to an early solution to this acute problem of spent wash utilization. Presently,the large quantity of spent wash is being stored in a open unlined earthen lagoon for cooling and bringing down the biological oxygen demand values.This storage system has tremendous hazardous effects on ground water pollution and ecosystem. The salinity of ground water was also increased due to seepage of spent wash.

The problem of spent wash is its excessive biological oxygen demand, chemical oxygen demand, and electrical conductivity. This can be overcomed due to either application of effluent of the proper dilution (1:50) with irrigation water or pre-planting application (40 to 60 days before planting) to give sufficient time for natural oxidation of organic matter. Spent wash can also be utilized in agriculture by making compost with crop residues due to its manurial values.

Many research conclusions indicate that, spent wash is non toxic, highly bio-degradable liquid, purely plant origin contain large quantity of soluble organic matter and plant nutrients , which sugarcane plant has absorbed from the soil (Kiran and Phagot, 2010). Raw and post biomethanated spent wash contain organic matter, and plant nutrients particularly K, S, N and P which can be applied to arable land as irrigation, manure as well as an amendment.

Mahimairaja and Nanthi (2004) reported that spent wash contains considerable amount of plant nutrient, organic matter, Ca^{2+}, Mg^{2+}, SO_4^{2-} and Cl^- in appreciable quantity which may be helpful in reclaiming the sodic soil similar to that of gypsum effect.

Kaushik *et al.* (2005) showed that, application of 50 per cent post bio-methanated effluent along with bio amendment proved useful for improving properties of sodic soil.

In India, there are 14.6 million ha of salt affected soil. Out of that 6.9 million ha is sodic soil. These soils are predominated with salts *viz.*, $NaHCO_3$ and Na_2CO_3 which are capable of alkali hydrolysis. The sodicity hinders agricultural production by detereorating the soil physical conditions and ionic environment. Sodic soils due to its high exchangeable sodium percentage (ESP) and pH ≥ 8.5 possess poor physical properties and microbial activity. Higher concentrations of sodium carbonate and bicarbonate in these soils reduce the availability of nitrogen, potassium, zinc and iron, which affect productivity of soils (Sen, 2003). It is proved that, spent wash helps in reclamation of sodic soil and enhance soil biological properties when used in low dose at 30 to 180 m^3 ha^{-1} (Gore, 2009). The reclamation essentially requires a soluble source of calcium whether mobilized from native calcium carbonate or added externally through soil amendment. Press mud, a sugar factory waste is a rich source of calcium (Carbonation process, 61 % calcium carbonate or organic matter Sulphitation process, 26 % organic carbon), can act as an effective ameliorant for sodic soil. Likewise spent wash, a distillery waste is acidic (pH 4.0). Effluent capable of generate gypsum in the soil from the native calcium carbonate of the calcareous sodic soil. Quantity of essential plant nutrients present in the spent wash has tremendous potential for its alternative use in the form of compost. This would help in maintaining soil fertility and substitute for considerable quantity of fertilizer nutrients, which are otherwise costly in agriculture.

Environmental and agricultural scientists are concerned for the safe disposal of spent wash with minimum detrimental effects on natural resources. The ill effects of spent wash need to be eliminated by addition of spent wash in to material like baggasse, press mud cake, sugarcane trash, pearl millet byre waste, wheat cut straw and chickpea straw or crop residues of different crops and bio-composting of the mixture before return to agricultural land hold good promise. Such spent wash could be utilized by dilution techniques with good quality water for irrigation purpose to the field crops.However; this technique has limitations due to water scarcity problems. The use of liquid spent wash as organic manure to the sugarcane crop could be good alternative to increase the cane yield significantly without detereoration of soil properties. There are limited reports regarding preparation of good quality compost by mixing raw spent wash, press mud cake, sugarcane trash, bagasse, wheat cut straw, chickpea straw, cattle byre waste

(FYM) etc.this can be used as manure recycling of organic waste through composting method which is the key technology for production of organic manures. Millions of farmers in developing countries need adequate resources for augmenting the crop productivity. Poor soil management ensuring continued maintenance and build-up of soil fertility is indispensable for greater productivity from the agricultural lands. Due to energy crisis, cost of fertilizers and poor purchasing power of marginal and small farmers, it is imperative to develop strategy to use wastes to their maximum potential with proper technology for improving soil fertility.

Now a days, there is an acute shortage of food grains throughout the world. Global market is now open to Indian farmers to sell their agricultural commodities. Hence, farmers are adopting modern agricultural techniques to increase their crop production. The available nutrient sources are not sufficient to meet the increasing nutrient demand of the crop. In order to meet increasing demand of plant nutrients, it is imperative to exploit all the alternative available resources of plant nutrients.

Looking to the scope and potential of post biomethanated spent wash and its nutrient content an experiment was conducted to study the effect of raw spent wash and post biomethanated spent wash on soil properties, growth, yield and nutrient uptake of *suru* sugarcane crop grown on Vertisol (normal and sodic soils).

As estimated the availability of crop residue is to the tune of 30 million tonnes (Tarafdar *et al.* 2008) in India, which can be utilized for manurial purpose. There are limited reports regarding utilization of good quality compost by using raw and post bio-methanated spent wash with press mud cake, sugarcane trash, baggasse, wheat cut straw, chickpea straw etc. which can be used as manure for crop production. Hence, the research project on utilization of raw spent wash and bio-methanated spent wash as manure on different types of the soils (normal and sodic) for sugarcane production has been planned with the following objectives.

1.1 Objectives

1. To assess the characteristic properties of raw spent wash, post bio-methanated spent wash and bio-composts prepared from raw and post bio-methanated spent wash.
2. To study the nitrogen mineralization characteristic of bio-composts.
3. To assess the effect of bio-composts prepared from raw and post bio-methanated spent wash on soil properties of normal and sodic soils.
4. To assess the effect and use of bio-composts on yield, quality and nutrient uptake by *suru* sugarcane and to study the performance of bio-composts in both the soils.

2. REVIEW OF LITERATURE

The disposal of industrial effluents like spent wash has severe problems. The huge amount of spent wash is discharged at the time of manufacturing of the alcohol from the sugar factories. Therefore, Central Pollution Control Board (CPCB) is always thinking about disposal of spent wash and looking forward as a source of plant nutrient and material for improvement of soil properties. Many research workers have reported significant effects of spent wash for crop production. The review pertaining to spent wash, it's utilization for crop production and effect on soil properties is presented in this chapter under different subhead.

2.1 Composition of raw spent wash

Singh *et al.* (1980), Patil *et al.* (1987) and Yadav (1989), analyzed spent wash/distillery effluents and found that, pH ranged from 3.5-5.04 (highly acidic) BOD from 45000 to 55000 and COD from 90000 to 110000 mg L^{-1}.

Manohar Rao (1983) reported that, spent wash contain nutrient such as nitrogen (1,200 to 1,500 mg L^{-1}), phosphorous (40 to 70 mg L^{-1}), potassium (8,000 to 13,000 mg L^{-1}) and iron (50 to 150 mg L^{-1}).

Kulkarni *et al.* (1987) stated that, spent wash was a major pollutant because of its high organic contents. The high BOD caused depletion of dissolved oxygen and proved very harmful to aquatic life. They classified spent wash as dilute liquid organic fertilizer with high potassium content and further stated that it contained about 90- 93 per cent water and 7-10 per cent solids. The 75 per cent solids were organic and 25 per cent inorganic. Nitrogen available mostly in organic form behaving as a slow release fertilizer, better than most inorganic N sources. The two-third of phosphorus was in organic form. The metabolic availability of which was more than any inorganic source. It also contained important secondary elements like Ca^{2+}, SO_4^{-2} and Mg^{2+} as well as trace elements such as Cu^{2+}, Mn^{2+} and Zn^{2+}.

Patil *et al.* (1987) stated that, spent wash was highly acidic and carried huge organic load and total solids. It contained a good amount of potassium and high concentration of chlorides and sulphates.

Chang and Li (1989) reported that vinnasse contained 16 per cent organic matter and one per cent K_2O.

Singh (1992) reported that the effluent from the distillery of organic chemicals did not contain any harmful matter in it. The high organic substances of the effluents can be recycled back for crop production and soil by developing appropriate technology. The distillery spent wash contained 0.2 g L^{-1} ammoniac nitrogen, 10.73 g L^{-1} potassium and 0.168 g L^{-1} phosphorus. The pH, COD, BOD of the spent wash obtained were 4.2, 77.7 g L^{-1}, 35.7 g L^{-1}, respectively. It also contains some amount of calcium, magnesium silicates and chlorides with traces of iron and copper.

The spent wash has dark brown colour and an objectionable odour. Its dark brown colour is due to the presence of brown polymer called melanoidins which are formed by the mallard amino carbonyl reaction.

Kitts *et al.* (1993) reported that, melanoidins compound highly recalcitrant and have antioxidant properties which render them toxic to many microorganisms, typically present in waste water treatment processes.

Patil (1994) reported that the spent wash contained Fe (34.8 ppm), Mn (12.7 ppm), Zn (4.61 ppm), Cu (3.65 ppm), Cr (0.64 ppm), Cd (0.48 ppm) and Co (0.08 ppm) with an EC value of 16.5 dSm^{-1}.

Ramadurai and Gerard (1994) reported that, the distillery effluent contains approximately 1.0-1.6 per cent N, 1.0-3.0 per cent P_2O_5, 1.0-2.02 per cent K_2O, 1.0-4.0 per cent CaO, 0.5-1.5 per cent MgO and traces of iron, manganese, copper and zinc.

Rajukannu and Manickam (1997) and Valliappan (1998) found that, spent wash was acidic (pH 3.94 to 4.30) and loaded with organic and inorganic salts, resulted in high EC (30-45 dSm^{-1}). Nitrogen content in spent wash was ranged from 1600 to 4220, phosphorous from 225 to 3038, potassium from 9600 to 17475, calcium from 2050 to 7000, magnesium from 1715-2100, sulphate from 3240 to 3425 and chloride from 7238 to 42096 mg L^{-1}.

Murugraghavan (2002) detected the presence of appreciable amount of plant growth promoters *viz.*, gibberellic acid (3246 to 4943 mg L^{-1}) and indol acetic acid (25 to 61 mg L^{-1}) in spent wash.

Joshi (2006) reported that, the distillery waste water known as spent wash is characterized by its colour, high temperature, low pH and high ash content. It contains high percentage of dissolved organic and inorganic matter of which 50 per cent may be present as reducing sugars. It contains about 90-93 per cent water and 7-10 per cent solids, sugars from 2-29 per cent and protein from 10-11 per cent in the dry spent wash. The metals present in spent wash are Fe (348 mg L^{-1}), Mn (12.7 mg L^{-1}), Zn (4.61 mg L^{-1}), Cu (3.65 mg L^{-1}), Ca (0.64 mg L^{-1}) and Cd (0.48 mg L^{-1}).

Mallika *et al.* (2003) reported that the untreated spent wash was dark brown in colour with high loads of suspended and dissolved solids. The pH of untreated spent wash was acidic. The EC of untreated spent wash was higher.

Joshi *et al.* (1994) characterized the untreated spent wash their properties are given in Table 1.

Table 1. Characteristics of untreated spent wash

Sr. No.	Chemical parameter	Untreated spent wash
1.	pH	3.5-4.5
2.	EC (dSm^{-1})	15-38
3.	BOD (mg L^{-1})	28,000-50,000
4.	COD (mg L^{-1})	90,000-1,00,000
5.	Nitrogen (mg L^{-1})	1,000-1200
6.	Total phosphorus (mg L^{-1})	30-50
7.	Total potassium (mg L^{-1})	9,000-13,000
8.	Sulphur (mg L^{-1})	1200-3000

Haroon and Bose (2004) studied the composition of untreated distillery effluent and reported that untreated distillery effluent was rich in potassium.

2.2 Characterization of post biomethanated spent wash

Joshi *et al.* (1994) characterized post bio methanated spent wash its important chemical properties are given in Table 2.

Table 2. Characteristics of post methanation spent wash

Sr.No.	Chemical parameter	Post methanation effluent
1.	pH	7.5-8.0
2.	EC (dSm^{-1})	8.5-23
3.	BOD (mg L^{-1})	4,000-5,000
4.	COD (mg L^{-1})	20,000-25,000
5.	Nitrogen (mg L^{-1})	260-300
6.	Total phosphorus (mg L^{-1})	18-20
7.	Total potassium (mg L^{-1})	6,000-7,000
8.	Sulphur (mg L^{-1})	800-1,000

Ramadurai and Gerard (1994) reported that the distillery effluent, which comes out after biomethanation is rich in macro and micronutrients. One cubic meter of primary treated distillery effluent contained 1.5 kg N, 0.25 kg P, 10 kg K and 15 kg digested organic matter. The BOD and COD levels of this effluent can be lowered by composting it with the press mud obtained as waste product from sugar industry. The composting varied with the quality of cane and process of cane juice clarification.

Joshi *et al.* (1996) characterized distillery effluent and noticed that it has extremely large volume, foul odour, dark coffee colour, highly biodegradable characters, dissolved solid content. The post machination effluents showed high BOD (5000-7000 mg L^{-1}) and COD (>40,000 mg L^{-1}) putrefying odour and dissolved solids.

Sukanya and Meli (2002) reported that pH of bio-methanated spent wash was 7.8 and contained BOD (4600 ppm), COD (26,000 ppm), total N (0.19 per cent), total P (6 ppm), total K (535 ppm), calcium (100 ppm), magnesium (120 ppm) and sodium (20 ppm).

Mallika *et al.* (2003) reported that the primary treated spent wash was reddish brown in colour, with high loads of suspended and dissolved solids. The pH of post biomethanated spent wash was alkaline in nature. The nitrogen content of primary treated spent wash was 1200 mg L^{-1}, while phosphorus content was 450 mg L^{-1}. The potassium content was very high about 10000 mg L^{-1}(Table 3).

Haroon and Bose (2004) studied the composition of primary treated distillery effluent and reported that the primary treated distillery effluent was alkaline in nature having low BOD (5,625 mg L^{-1}) and COD (45000 mg L^{-1}). Primary treated distillery effluent was rich in potassium. The detail characteristic properties are given in Table 3.

Table 3. Characteristics of primary treated distillery effluents

Sr. No.	**Chemical parameter**	**Mallika *et al.* (2003)**	**Haroon and Bose (2004)**
1	pH	8.2	8.0
2	EC (dSm^{-1})	36.3	32.50
3	Total solids (mg L^{-1})	46000	81000
4	Temperature (^0C)	37	-
5	COD (mg L^{-1})	35000	45000
6	BOD (mg L^{-1})	5000	5625
7	Nitrogen (mg L^{-1})	1200	1740
8	Total phosphorus (mg L^{-1})	450	260
9	Total potassium (mg L^{-1})	10000	115000
10	Calcium (mg L^{-1})	11000	11050
11	Magnesium (mg L^{-1})	1200	2200
12	Sodium (mg L^{-1})	400	510
13	Chlorides (mg L^{-1})	9400	11200
14	Sulphur (mg L^{-1})	1200	2440

Ranjun (2007) studied the composition of post biomethanated spent wash and reported that the post biomethanated spent wash was nearly neutral to slightly alkaline in reaction with pH 7.23 and electrical conductivity (EC) was 42.83 dSm^{-1}. The BOD and COD was 6000 and 26,666 mg L^{-1}, respectively. It contains very high concentration of potassium i.e. 1.0 per cent, 0.162 per cent of nitrogen and 0.029 per cent of phosphorus. Among the cations, calcium was highest (3416.6 mg L^{-1}) followed by magnesium (27000 mg L^{-1}), sodium (26000 mg L^{-1}), chlorides (2533.33 mg L^{-1}) and sulphates (2618.4 mg L^{-1}). The micronutrient content in bio-methanated spent wash was Fe^{2+} (65.7 mg L^{-1}), Mn^{2+} (0.5 mg L^{-1}), Zn^{2+} (8.33 mg L^{-1}) and Cu^{2+} (19.66 mg L^{-1}).

Tripathi *et al.* (2007) reported that post biomethanated distillery effluent is a rich source of potassium. The post bio-methanated distillery effluent is acidic in nature (pH 5.9) with values of EC (8.5 dSm^{-1}), organic carbon (1.13 per cent) N (3,279 ppm), P (33 mg L^{-1}), K (9,875 mg L^{-1}), BOD (5000) and COD (25,000 mg L^{-1}).

Khatal (2008) noticed that post biomethanated spent wash was alkaline in reaction with high concentration of soluble salts. The N (0.17 per cent), P (0.02 per cent) and K (0.99 per cent) was present in appreciable quantity. Among the cations Ca^{2+}, Mg^{2+}, Na^{+} and anions like Cl^{-} and SO_4^{2-} were dominant with appreciable quantity of Fe (58 mg L^{-1}). The BOD (5,450 mg L^{-1}) and COD (24,740 mg L^{-1}) of the effluent was in safe limit as prescribed by CPCB.

Selvamurugan *et al.* (2011) reported that post bio-methanated spent wash was dark brown in colour, unpleasant odour having total dissolved solids (42300 mg L^{-1}), total suspended solids (6100 mg L^{-1}) and total solids (48400 mg L^{-1}), pH was (7.57) with values of EC (33.45 dSm^{-1}), BOD (11400 mg L^{-1}), COD 42800 mg L^{-1}, organic carbon (25200 mgL^{-1}). Nitrogen (1700 mg L^{-1},) Phosphorous (248 mg L^{-1}) Potassium (480 mg L^{-1}), Calcium (2120 mg L^{-1}), Magnesium (1680 mg L^{-1}), etc.

Chidankumar *et al.* (2010) studied the chemical composition of primary treated spent wash and diluted spent wash and its chemical properties are given in Table 4.

Table 4. Chemical composition of spent wash

1.	pH	7.36	7.24
2.	EC (μSm^{-1})	28800	10020
3.	Total solids (mg L^{-1})	46140	20870
4.	Total dissolved solid (mg L^{-1})	35160	10140
5.	Total suspended solids (mg L^{-1})	10540	4380
6.	Settable solids (mg L^{-1})	10070	3010
7.	COD (mg L^{-1})	40530	10228
8.	BOD (mg L^{-1})	16200	4800
9.	Bicarbonates (mg L^{-1})	13100	4200
10.	Total phosphorus (mg L^{-1})	30.26	6.79
11.	Total potassium (mg L^{-1})	7200	2400
12.	Calcium (mg L^{-1})	940	380
13.	Magnesium (mg L^{-1})	1652	542.22
14.	Sodium (mg L^{-1})	480	240
15.	Chlorides (mg L^{-1})	5964	3164
16.	Iron (mg L^{-1})	9.2	5.20
17.	Manganese (mg L^{-1})	1424	368
18.	Zinc (mg L^{-1})	1.28	0.41
19.	Copper(mg L^{-1})	0.276	0.074
20.	Sulphur (mg L^{-1})	74.8	22.6

Janaki and Velu (2010) analysed the post bio-methanatd spent wash and reported that, colour of post bio-methanated spent wash was dark brown, unpleasant odour, 84 % moisture, 7.65 pH and EC was 41.95 $dSm^{-1.}$ The chemical composition composition is given in Table 5.

Table 5. Chemical composition of post bio-methanated spent wash

Sr. No.	Chemical parameters	PBMSW
1.	Colour	Dark brown
2.	Odour	Unpleasant
3.	Moisture (per cent)	84
4.	Specific gravity (g cc^{-1})	1.11
5.	pH	7.65
6.	EC (dSm^{-1})	41.95
7.	Total suspended solids (mg L^{-1})	6950
8.	Total dissolved solid (mg L^{-1})	44,000
9.	Total solids	50,950
10.	Organic Carbon (per cent)	13.7
11.	COD (mg L^{-1})	8,900
12.	BOD (mg L^{-1})	34,000
13.	Nitrogen (mg L^{-1})	1,200
14.	Total phosphorus (mg L^{-1})	760
15.	Total potassium (mg L^{-1})	13,250
16.	Calcium (mg L^{-1})	1293
17.	Magnesium (mg L^{-1})	896
18.	Sodium (mg L^{-1})	521
19.	Chlorides (mg L^{-1})	9400
20.	Bicarbonate (mg L^{-1})	3120
21.	Sulphate (mg L^{-1})	1250
22.	Iron (mg L^{-1})	63.0
23.	Manganese	4.5
24.	Zinc (mg L^{-1})	5.2
25.	Copper (mg L^{-1})	4.7

Rath *et al.* (2010) analysed post bio-methanated spent wash and their chemical composition is reported in Table 6.

Table 6. Chemical composition of PBM spent wash

Sr. No.	Chemical parameters	PBMSW
1.	Colour	Dark brown
2.	Odour	Unpleasant
3.	Moisture (per cent)	84
4.	Specific gravity (g cc^{-1})	1.11
5.	pH	7.23
6.	EC (μSm^{-1})	28700
7.	Total suspended solids (mg L^{-1})	9980
8.	Total dissolved solid (mg L^{-1})	27240
9.	Total solids(mg L^{-1})	35340
10.	Settleable solids	9860
11.	COD (mg L^{-1})	30520
12.	BOD (mg L^{-1})	15300
13.	Nitrogen (mg L^{-1})	420
14.	Bicarbonates (mg L^{-1})	12200
15.	Total phosphorus (mg L^{-1})	28.36
16.	Total potassium (mg L^{-1})	6500
17.	Calcium (mg L^{-1})	920
18.	Magnesium (mg L^{-1})	753.25
19.	Sodium (mg L^{-1})	420
20.	Chlorides (mg L^{-1})	5626
21.	Sulphate (mg L^{-1})	5100
22.	Iron (mg L^{-1})	6.3
23.	Mangenese (mg L^{-1})	1429
24.	Zinc (mg L^{-1})	1.09
25.	Copper (mg L^{-1})	0.265

Kalaiselvi and Mahimairaja (2010) analysed post bio-methanated spent wash and chemical composition given in Table 7.

Table 7. Chemical composition of distillery spent wash

Sr. No.	Chemical parameter	PBMSW
1.	Colour	Dark brown
2.	Odour	Unpleasant burnt sugar
3.	pH	7.1
4.	EC (dSm^{-1})	38
5.	Total dissolved solid (mg L^{-1})	50000
6.	Total suspended solids (mg L^{-1})	3300
7.	Total solids (mg L^{-1})	53300
8.	BOD (mg L^{-1})	12800
9.	COD (mg L^{-1})	35000
10.	Carbon (mg L^{-1})	24
11.	Nitrogen (mg L^{-1})	420
12.	Phosphorus (mg L^{-1})	40
13.	Potassium (mg L^{-1})	9097
14.	Sodium (mg L^{-1})	357
15.	Calcium (mg L^{-1})	4600
16.	Magnesium (mg L^{-1})	1752
17.	Chlorides (mg L^{-1})	13471
18.	Bicarbonate (mg L^{-1})	195
19.	Sulphate (mg L^{-1})	947
20.	Total Sugar (per cent)	3.49
21.	Reducing Sugar (per cent)	1.77
22.	Iron (mg L^{-1})	78
23.	Mangenese (mg L^{-1})	5.3
24.	Zinc (mg L^{-1})	7.20
25.	Copper (mg L^{-1})	5.5

2.3 Composition of organic residues

Different crop residues with varying biochemical composition are generally used for preparation of bio-compost /compost.

Mohan Sing (1991) utilized the sugarcane trash for composting containing N (0.49 per cent), P (0.5 per cent), K (0.57 per cent), organic carbon (46.5 per cent) and ash (6.89 per cent) with C/N ratio 95.0.

Singh *et al.* (1995) reported the chemical composition of wheat cut straw containing total nitrogen (0.35 per cent) with C/N ratio of 133.

Rao and Tarfdar (1998) used the pearl millet stalk which had carbon 44.6 per cent, total nitrogen 0.5 per cent with C/N ratio of 89.1.

Manna *et al.* (2000) estimated that wheat straw residues composed of total organic carbon 48.9 per cent, total N 0.52 per cent with C/N ratio of 94.0.

Ganguly and Singh (2004) used wheat straw residues for preparation of vermicompost and reported that the wheat cut straw residues contained 0.62 percent N, 0.14 per cent P, and 0.42 per cent K with C/N ratio 70.9.

2.4 Changes in chemical composition during decomposition of crop residues

The changes in chemical and biological properties of compost and FYM during composting determine the extent of decomposition.

Mathur *et al.* (1980) have analysed the compost prepared from wheat cut straw,farm wastes, green leaves and enriched with rock phosphate and reported that the organic carbon content in raw material was as high as 40 per cent in the beginning of incubation which was considerably reduced after 30 days and it was further decreased with time. They also observed that there was an increase in nitrogen content in the compost after 130 days, which might be due to reduction in the mass of the material and release of nitrogen after decay of the microorganisms. The C/N ratio of the compost was narrowed down considerably with time.

Shinde and Rote (1983) prepared compost from sugarcane trash using dung, super phosphate and microbial culture by heap method for a period of 5 months and observed that there was significant decrease in C/N ratio, organic carbon and increase in total N up to 60 days of period and thereafter decrease in total. The organic carbon decreased from 41.40 to 19.18 at the end of period while total N increased from 1.54 to 1.62 at 60 days and decreased to 1.39 at the end of composting period.

Asija *et al.* (1984) studied the effect of method of preparation and enrichment on the quality of manure and reported that total nitrogen percentage was higher in manure prepared in pits than in heaps. C/N ratio of decomposing mixtures narrowed down with time. Phosphorous enrichment with rock and SSP preserved nitrogen in manures. The pH, organic carbon and ammonia recorded a decline while there was a rise in nitrate levels.

Bhanwase *et al.* (1994) enriched the sugarcane trash with rock phosphate, urea, pyrites and decomposing cultures and decomposed for 120 days and reported the changes in organic carbon, total nitrogen and C/N ratio. The organic carbon decreased from 44.0 to 29.9 per cent, total N increased from 0.36 to 0.77 per cent and C/N ratio decreased from 122.3 to 33.7 at the end of composting.

Talashilkar *et al.* (1999) observed the changes in C/N ratio during composting of farm waste as influenced by earthworm activity. They stated that there was a gradual and considerable reduction in the C/N ratio with advancement in the period up to 150 days. The C/N ratio of farm wastes decreased from its first day value of 76.3 to 69.2, 25.9, 22.1, 18.9 and 17.8 at 30, 60, 90, 120 and 150 days of composting respectively.

Manna *et al.* (2000) studied the changes in ash, organic carbon, total N and C/N ratio of wheat cut straw compost enriched with rock phosphate, pyrites, fresh cow dung and microbial cultures as cellulose decomposer. Organic carbon decreased from 36.0 per cent to 25 per cent, total N increased from 1.46 per cent to 1.83 per cent and C/N ratio decreased from 24.3 to 13.7 at 30 days and 120 days of composting period, respectively.

2.5 Characterization of bio-compost/manure.

Patil *et al.* (1984) reported the chemical properties of FYM showing pH 7.6, moisture and mineral matter (ash) content to the tune of 22.7 per cent and 39.7 per cent respectively. The N, P, K content was 1.4, 0.83 and 0.79 per cent, respectively with C/N ratio 15.1.

Bhardwaj and Gaur (1985) reported that cattle manure contained 1.06 per cent N, 0.52 per cent P, 0.95 per cent K and 0.57 per cent Fe.

Lax *et al.* (1986) characterized different organic manures for pH, EC, ash, organic carbon and water soluble organic carbon. The cattle manure showed pH between 7.5 to 8.3, EC from 5.29 to 12.13 dSm^{-1}, ash 27.1 to 35.4 per cent, and organic carbon ranged between 1.07 to 2.60 per cent.

Bhanwase *et al.* (1994) reported that the phospho-compost prepared from sugarcane trash plus soybean straw had 22.6 per cent organic carbon, 0.89 per cent total N, 0.75 per cent total P_2O_5, C/N ratio 25.4, NH4-N 550 ppm and NO3–N content 570 ppm and phospho-compost prepared from sugarcane trash contains 26.9 per cent organic carbon, 0.77 per cent total N, 0.8 per cent total P_2O_5, 33.7 C/N ratio, 490 ppm NH4-N and 527 ppm NO3–N etc.

Patil (1994) characterized the FYM for pH (7.5), EC (13.5 dSm^{-1}), ash (24.0 per cent), organic carbon (41.3 per cent), organic matter (71.0 per cent), and C/N ratio (24.3). He also estimated the macronutrient and micronutrients status of FYM and reported that total N, P, K and S were 1.7, 1.1, 1.5 and 1.5 per cent, respectively. The micronutrients *viz.,* Fe, Mn, Zn and Cu were 10771, 486, 140 and 71 mg kg^{-1}, respectively.

Mishra (1998) evaluated the basic properties of FYM and reported the chemical properties as pH (8.10), CEC (52.0 Cmol(P^+) kg^{-1}) organic carbon (21.06 %) total N (0.95 per cent), total P (0.18 %) , total K (0.24 per cent), total S (1.24 %) and C/N ratio (22.12)

Jothimani and Maheshwari (2002) reported the chemical composition of FYM containing macro and micro nutrients. Micronutrients like Fe contain 3350 mg kg^{-1}, Mn 1500 mg kg^{-1} and Zn 262 mg kg^{-1}.

Pawar (2004) reported the physical and chemical properties and nutrients status of compost prepared from wheat straw, sugarcane trash and bajra stubble. The colour of wheat straw compost, sugarcane trash compost and bajra stubble compost was brown yellow (10YR 6/6), yellowish brown (10YR 4/4 and very dark bown (10 YR 2/3), respectively. The pH of these compost was 6.75, 7.06 and 7.43 while EC was 2.03, 0.77 and 1.22 dSm^{-1} respectively. Wheat straw compost contained 0.66, 0.16 and 0.92 per cent N, P and K, respectively. While that of sugarcane trash compost contained 0.60, 0.19 and 0.67 per cent N, P and K, respectively. Bajra stubble compost contains 0.77 per cent N, 0.72 per cent P and 0.99 per cent K.

2.5.1 Characterization of spent wash bio-compost

Glioria *et al.* (1973) proposed mixing of vinasse filter cake and sugar factory waste for preparation of compost with most economical means of using them as a fertilizer. The spent wash was neutrialised with lime and concentrated at 75^0 to 80^0 brix in a multiple effect evaporator. The concentrated was used in dried filter mud or bagasse and sold to the farmers as manure (Dubey *et al.* 1977).

Subba Rao (1988) effectively converted distillery waste in to humus using filter materials like press mud and bagasse, by aerobic composting. The process involved preparation of compost pit of 1.5 meter depth and convenient length and spent wash and press mud were to be mixed in a proportion of 1:2 and turned mechanically with two days interval for a period of 5 to 6 days. Composting of spent wash proved to be one of the viable technologies for distillery waste disposal.

Subba Rao (1988) prepared good quality compost prepared by mixing distillery effluents, press mud cake, sugarcane trash, baggasse and sugar factory waste which can be used as a manure.

Zende and Patil (1988) prepared compost by mixing 50,000 litres of spent wash and 50 tonnes of press mud with the help of JCB excavator at an interval 3-4 days upto 10 days. The manurial value of the compost indicated that it contained 0.7-1.3 % P_2O_5 and 2.3 -3.1 % K_2O. The C: N ratio was wider indicating incomplete decomposition of the compost material and should be applied one to two months before planting.

Following composition of spent wash-pressmud compost as is given in Table 8 reported by Patil (1991) and Kale (1993).

Table 8. Composition of spent wash pressmud compost

Sr. No.	Particular	Patil (1991)	Kale (1993)
1	pH (1:2.5)	6.59	7.15
2	EC (dS/m)	13.95	13.50
3	Organic corbon (per cent)	28.02	31.84
4	Nitrogen (per cent)	1.83	0.79
5	Phosphorus (per cent)	0.86	0.79
6	Potassiuum (per cent)	2.30	1.90
7	Calcium (per cent)	8.49	5.50
8	Magesium (per cent)	1.21	1.68
9	Sodium (per cent)	0.11	0.61
10	Sulphate (per cent)	3.18	1.37
11	Chloride (per cent)	1.02	0.25
12	Iron (ppm)	16450	9000
13	Manganese (ppm)	695	420
14	Zinc (ppm)	71	995
15	Copper (ppm)	170	97

Selvamurugan *et al.* (2011) prepared spent wash press mud bio-compost and its characterization is given in Table 9.

Table 9. Characteristics of press mud cake bio-compost

Sr. No.	Chemical parameter	PBMSW
1	pH	7.50
2	EC (dSm^{-1})	8.80
3	Organic carbon (per cent)	24.80
4	Total nitrogen (per cent)	1.54
5	Total phosphorus (per cent)	1.08
6	Total potassium (per cent)	2.95
7	Calcium (per cent)	3.20
8	Magnesium (per cent)	2.00
9	Sodium (per cent)	1.05
10	C/N ratio	16.10
11	Copper (mg kg^{-1})	45.00
12	Zinc (mg kg^{-1})	105.00
13	Iron (mg kg^{-1})	2000.00
14	Mangenese (mg kg^{-1})	190.00

Khambe *et al.* (1992) reported that, spent wash press mud compost contained considerable amount of micronutrients which were helpful to improved soil quality. These essential elements like Zn, Fe, and Mn were present in compost at desired concentration. Thus, spent wash press mud compost provided micro and macro elements.

2.5.2 Characterization of humic substances in the organic manure/compost

The characteristics of the humic substances extracted from FYM and /or compost varied with the rate of decomposition and humification. According to Kononova (1966) HA and FA were linked by a sequence of single inter- convertible chain.

Chen *et al.* (1977) characterized the humic substances based on E4/E6 ratio and found that E4/E6 ratios of humic and fulvic acids were mainly governed by the particle size and molecular weight. They also reported that, E4/E6 ratios of humic fractions were affected by pH, free radical concentration, contents of organic carbon and total acidity.

Investigation on humification parameters carried out to evaluate the maturity of organic waste by Saviozzi *et al.* (1983). They reported that the humic acid and fulvic acid contents increased and organic carbon and C/N ratio were decreased over a period of 120 days of decomposition.

Singh and Amberger (1990) reported that relative quantities of humic acid increased with increase in composting time of wheat straw. While Fulvic acid production decreased after 30 days of composting. They also stated that during composting of wheat starw, fulvic acids were produced initially in high quantities and then they were converted gradually in to humic acids with maturation of compost.

Patil (1994) chacterized FYM collected from the Cattle Improvement Project, MPKV, Rahuri for its humic substances. The humic fractions viz. humic acid, fulvic acid and humin content were 15.6, 22.8 and 61.6 per cent, respectively. The higher content of FA reflected the HA/FA ratio about 0.68. The E4/E6 ratios of HA and FA were 4.5 and 6.4 respectively, indicating highly aromatic nature of humic acid.

2.6 Maturity indices of compost/manures

The principal requirement of compost and/or manures for safe use in soil is its degree of stability or maturity, which implies stable organic matter content and the absence of phytotoxic compounds and plant or animal pathogens. Maturiry is associated with plant growth potential or phytotoxicity (Iannotti *et al.* 1993), whereas stability is often related with the composts microbial activity. A number of criteria and parameters have fixed for testing compost made from city refuse. Physical characteristics such as colour, odour and temperature gave a general idea of the decomposition stage reached, but gave little information as regards the degree of maturation. Hence the chemical methods viz., measurement of the C/N ratio in the solid phase and in water extract, inorganic nitrogen, the cation exchange capacity as well as the degree of organic matter humification were widely used (Bernal *et al.* 1998).

2.6.1 Physical indices for compost

2.6.1.1 Temperature

Kalaiselvi and Ramasamy (1996) reported that the temperature of mature compost should be within 30-40 ^{0}C. In immature compost temperature builds up in compost pit, which might be due to the microbial activity.

2.6.1.2 Colour

Kalaiselvi and Ramasamy (1996) noted the tea brown colour of compost was the indication of maturity.

Jothimani and Maheswari (2002) and Subramanian (2002) reported that during composting of organic residues, a gradual darkening or melanization of the material take place. The final product after a sufficiently long period of maturation was a dark brown or almost black colour.

2.7 Chemical indices for composts

2.7.1 pH

Kalaiselvi and Ramasamy (1996) stated that the most common pH values of compost ranged between 6.5 and 8.0. The compatibility with plant growth was within the range of 5.5 to 8.0.

Rajbanshi and Singh (1998) stated that the rise in pH during the microbial decomposition of plant materials under aerobic conditions associated with decarboxylation of organic anions releasing CO_2. However, not all the CO_2 produced during composting resulted in pH rise.

2.7.2 EC

Kalaiselvi and Ramasamy (1996) reported that the amount of total soluble salt present in the compost indicated the maturity and they suggested that total salinity should not exceed 2 g salt L^{-1} and the concentration of sodium and chloride ions should be specified in mature compost. While Jothimani and Maheshwari (2002) suggested that the mature compost should have electrical conductivity (EC less than 1.50 dSm^{-1})

2.7.3 C/N ratio

This is criterion traditionally used to determine the degree of maturity and define its agronomic quality. While sometimes this value might to above 20 in relatively mature compost since part of the organic carbon might be in the form of compound more resistant to biodegradation and not immediately available to microorganisms (Jimenz and Garcia, 1989).

Kalaiselvi and Ramasamy (1996) reviewed that C/N ratio was the conventional index to establish the maturity of compost. This was based on the fact that during composting carbonaceous material was converted into microbial mass, CO_2, water and humus. Therefore, the ratio between carbon and nitrogen reduced progressively with the age of the composting.

Bernal *et al.* (1998) prepared seven different composts in a pilot plant by the Rutgers pile system using wide range of wastes, sewage, sludge, poultry manure, pig slurry, olive- mill waste water, city refuge and lignocellulose waste as cotton waste, maize straw and sweet sorghum, baggasse. Their chemical and biological properties were studied at four different stages of composting process revealed that the initial C/N ratio of wide range waste material decreased from 11.0-31.1 to 7.8- 11.8 after maturation, C/N ratio was less than 12.0 for a municipal waste compost considered as desirable maturity of compost.

Jothimani and Maheswari (2002) reported the C/N ratio between 15 to 20 as maturity indices for sugarcane trash compost prepared by Japanese method.

Subramanian (2001) reported that the commercially accepted compost should have C/N ratio less than 20.

2.8 Effect of spent wash bio-compost on physico-chemical properties of soil

Bajpai and Dua (1972) reported that due to addition of 20 times diluted spent wash the pH values was not affected, organic carbon content was decreased and nitrogen content was increased.

Jadhav and Sawant (1975) conducted laboratory experiments to study the influence of spent wash as irrigation water on some physical and chemical properties of non-calcareous medium black soil. They observed the slow increase in soil pH, where as EC, water soluble cations and anions, SAR and PAR ratio increased rapidly. Na^{+} and K^{+} increased in the spent wash treated soils. There was beneficial effect of periodical spent wash addition on organic carbon, available N, P, and K content of soil. The physical properties such as water retention, hydraulic conductivity and water stable aggregate were adversely affected due to addition of spent wash.

Chang and Li (1988) showed the little effect on soil pH, organic matter content, SAR, exchangeable sodium and phosphorous content over three crop seasons but significantly increased the conductivity, soluble salts and non exchangeable potassium it containing organic load, nutrient values etc.. Many researchers were applied spent wash for crop as a nutrient source by spraying, mixing in the soil in one time control, and their results were also significant as increasing the crop yield. Now a days, many sugar factories are providing facilities for distribution of spent wash by providing tankers. However, as such spent wash is being utilized for one time controlled land application for crop production. Continuous application of spent wash may lead to development of salinity due to presence of salt loads.

Therefore, these composting techniques may show some promises. The biocompost in combination with using waste crop residues like wheat cut straw, pearl millet straw, chickpea straw, as well as bagasse, sugarcane trash and press mud cake. Whatever, nutrients present in this different organic sources that can be utilize for preparing the biocompost in combination of spent wash.

Singh *et al.* (1980) found that addition of spent wash without dilution was very effective in increasing water intake rate of sodic soil. The exchangeable sodium percentage was reduced from 100 in the original soil to 2 in top 15 cm. They indicated that the spent wash application followed by irrigation rather than dilution of spent wash at the time of its application was very effective in reclamation of sodic soils.

Azmal and Khan (1983) reported increase in the soil salinity level and organic carbon content due to use of distillery waste water.

Li (1986) observed that heavy application of spent wash caused blockage of soil capillaries by organic matter present in it, which in turn affected all physical properties of soil. The bulk density of soil decreased from 1.40 to 1.32 (Patil, 1994).

Pawar *et al.* (1992) found that addition of diluted spent wash decreased pH and EC. There were significant changes in exchangeable K, Ca and Mg content of soil. The nutrient supplying status of the experimental soil was improved considerably under pot culture condition.

Singh (1992) reported that, properties of soil changed with change in BOD levels of effluent water. The organic carbon content and EC of soil increased from 0.37 to 0.79 per cent, 0.60 to 0.80 dSm^{-1}, respectively. The available N, P, K and pH also increased significantly with increase in BOD level of effluent water. All these factors particularly affected in light textured soils.

Devarajan *et al.* (1998) reported that the effluent irrigation in banana significantly increased the pH, EC, OC and available nutrient content of the soils. In post harvest soil analysis pH increased from 7.03 to 7.87 the EC from 0.12 to 0.21 mmhos cm^{-1} and organic carbon from 0.65 to 1.15 per cent with increasing level of effluent addition. Potassium fertilizer could be withdrawn from fertilizer schedule under effluent irrigations. The EC, organic carbon, available N, P and K in soil were higher with the uses of effluent water than with normal water at the same level of fertilizer application. A significant increase in the available Ca, Mg and exchangeable Na content of the soil was also noticed with effluent additions. The infiltration rate of the soil was not affected by effluent application.

Ghugare (1994) stated that if spent wash was applied in smaller quantity and in diluted form, it did not show harmful effects on soil physical properties. The CEC of soil was increased due to improvement in soil texture. On the other hand, if spent wash applied to sandy, gravely or murum soil, there was improvement in soil texture and other soil properties (Robina *et al.* 1986 and Li, 1986).

Joshi *et al.* (1994) surveyed 23 distilleries in India and reported that the marked increase in EC of top 30 cm soils in Maharashtra and had no significant change in soil of Uttar Pradesh and coastal Andhra Pradesh due to continuous spent wash application on land. The infiltration rate of the soils was remained unaffected due to application of spent wash.

Zalawadia and Raman (1994) studied the effect of distillery waste water with graded fertilizer levels on sorghum yield and soil properties and reported that different levels of fertilizer as well as the quality of water didn't influence the soil reaction values while EC, organic carbon and K content of soil were affected significantly with the use of effluent water when compared to normal water. Though the nitrogen and phosphorus availability also increased due to distillery waste water the magnitude was less than that of the change in potassium availability. The EC values reported were significantly higher in all the distillery waste water. The highest value was recorded in distillery water with 100 % fertilizer dose. Similarly, the organic carbon, available N, available P and available K were highest in the treatments which was irrigated with distillery water and fertilized with 100 % of recommended dose of fertilizer.

Devarajan and Oblisami (1995) reported that the effluent irrigation significantly increased the pH, EC, organic carbon and available nutrient content of the soil. Potassium fertilizer can be withdrawn from schedule under effluent irrigations. They found that pH was increased from 6.95 to 7.65 with effluent irrigations. The pressmud and gypsum applied soil recorded significantly lower pH. The EC of the soil showed increasing trend from 0.33 to 0.97 dSm^{-1} with increasing dilution of effluent irrigations.The available N, P, K, Ca and Mg content of the soils increased significantly by effluent irrigation. The significant increased in available K was due to the fact that the effluent contains 11,500 ppm K. The effluent irrigations significantly increased the trace metal level in soil (Zn, Fe, Cu and Mn) and this could be attributed to the fact that the treated effluent contains appreciable quantities of micronutrients. The infiltration rate of the soils was significantly reduced with effluent irrigation. The reduction in the infiltration rate was marginal.

Singh *et al.* (1995) reported that pH and EC of soil was unaffected by 3 years application of distillery effluents whereas soil organic carbon, N, P and K content increased significantly with increasing BOD levels of irrigated effluents.

Chaudhary (1998) revealed that application of spent wash at the time of sowing improved the fertility of both the soils under study, in respect of organic carbon, available N, P, and K. Highest available N, P and K values were observed due to application of K through only spent wash applied @ 116 ml/pot. However, no adverse effects on soil physical properties such as bulk density, porosity and hydraulic conductivity and chemical properties such as pH, EC were noticed due to application of spent wash. Thus result indicated that, spent wash could be used as a substitute or alternative for potassium to enhancing the growth, yield and uptake of nutrients and fertility of soil.

Singh and Bahadur (1998) conducted an experiment during 1993-95 to utilize distillery effluents having biological oxygen demand of 4620 mg L^{-1} for pre-sowing irrigation to maize (*Zea mays* L.) and its effect on growth and soil properties was monitored. Twelve pre-sowing irrigations with effluent of 4620 mg L^{-1} BOD had no adverse effect on the germination of maize but improved the growth and yields. The pH and EC of the soil was slightly increased, where as, the soil organic carbon, nitrogen, phosphorus and potassium content increased significantly with increase in the number of pre-sowing effluent irrigations.

Pathak *et al.* (1999) reported that distillery effluents contain a considerable amount of plant nutrients. In a field study, soil amendment with diluted post methanation distillery effluent increased the yield of wheat and rice grown in sequence. Organic carbon and available potassium content of post harvest soils were also increased. Saturated hydraulic conductivity, bulk density and volumetric water contents of the soils improved with effluent application. There was no change in pH after harvest of wheat and rice. The study showed that the effluent can be used as soil amendment. However, the EC of soil also increased indicating the possibility of salinity development in the long run with higher levels of effluent application.

Patil *et al.* (2000) in green house experiment observed that the increase in levels of spent wash increased the fertilizer status of soil in terms of available N, P and K.

Kayalvizhi *et al.* (2001) studied optimum dilution of the effluent for its direct application to standing sugarcane crop and its soil properties and reported that the changes in soil pH and soluble salts were found non significant due to application of effluent. The available nutrient contents of N, P and K were increased to the tune of 2 to 3 times with effluent application. The exchangeable sodium percentage was maintained below 15 and the increase in ESP was within one unit even after repeatedly application of distillery effluent. There was a progressive increase of exchangeable cations Viz., Ca^{++}, Mg^{++} and available micronutrients *viz.*, Fe, Cu, Mn and Zn. The dilution of 1:10 and 1:20 were found to be optimum for sandy loam and clay soils, respectively.

Murugaraghavan (2002) in case of Vertisol and Alfisol observed increase in SAR<3.62 and ESP <4.8 due to application of spent wash. However, these values were below the threshold levels. It suggests that even at higher rate, the spent wash applied is unlikely to cause any sodicity problem in these soils. Although initial enhancements in enzymes (*phosphatase, dehydrogenase* and *urease*) and microbial (Actinomycetes, yeast and bacteria) activities was evident in soil amended with the spent wash, no marked effect was observed at the end of 60 days incubation.

Hati *et al.* (2003) in an investigation conducted for three years during 1999-2002 on soybean-wheat cropping sequence evaluated the effect of graded levels of post methanation effluent (PME) on soil physical properties in a deep Vertisol of central India. The application of PME increased the organic carbon content and EC of the soil compared to control and 100 per cent NPK + FYM treatment. The organic C content was maximum in soybean treatment. The organic C content was maximum in soybean + wheat (11.2 g kg^{-1}) and minimum in control (5.2 g kg^{-1}). The EC increased from 0.47 dSm^{-1} in control to 1.58 dSm^{-1} in highest dose of PME (soybean + wheat). The PME treatments have not affected the soil pH. The application of PME showed a significant improvement in the physical properties of the soil. The mean weight diameter (MWD), water stable aggregation, saturated hydraulic conductivity, and water retention at 0.033 MPa suction were significantly more ($P<0.05$) while bulk density and penetration resistance was significantly less in PME-treated plots than that of control. The MWD showed a linear and positive relationship ($r=0.89$) with soil organic carbon.

Saliha (2003) reported that increase in the spent wash application resulted a notable decrease in the pH of soils and such effect was more pronounced in the presence of organic amendments. The decrease in soil pH might be attributed to the acidic nature of spent wash and release of organic acids during the decomposition. The EC of soil increased markedly due to accumulation of salts from spent wash. The concentration of available plant nutrients (available N, P and K) in soil increased substantially. Significant increase in organic carbon content of soils was also observed which could be ascribed to the addition of organic matter through spent wash application.

Kaushik *et al.* (2005) studied impact on various soil properties like EC, pH, total organic carbon (TOC), total nitrogen, available phosphorus, exchangeable cations K^+ Na^+, Ca^{2+} and anions, microbial population and soil enzyme activities were studied. Long-term application of PME proved useful in significantly increasing TOC total N, P and K, soil enzymatic activities in the soil but tended to build up harmful concentration of Na^+ that could be chelated by bio-amendments. In short term studies, application of 50 per cent PME along with bio-amendments proved to be the most useful in improving the properties of sodic soil.

Hati *et al.* (2007) reported that due to application of PBMSW the organic carbon, microbial biomass carbon and electrical conductivity (EC) of surface soil (0-10 cm) increased significantly while application of distillery effluent (DE) has not affected soil pH. The application of DE showed a significant improvement in the physical properties of the soil. The mean weight diameter (MWD), saturated hydraulic conductivity, water retention at field capacity and available water content were significantly ($P<0.05$) higher, while bulk density (BD) and penetration resistance of the surface soil were significantly lower ($P<0.05$) in all DE treated plots.The MWD showed a positive linear relationship with the organic carbon ($r=0.84$) and a microbial biomass carbon ($r=0.70$) of the soil. A significant ($P<0.01$) negative linear relationship ($r=0.70$) was reported between soil organic carbon and BD.

Anandakrishnan *et al.* (2008) reported that the application of post methanated distillery effluent to sugarcane crop has significantly increased soil organic carbon, available NPK, exchangeable cations (Ca + Mg) and available micronutrients in the post harvest soil of sugarcane. The PME applied at rate of 1.25 lakh litres per ha has resulted no any adverse effect on the soil properties. The PME has substituted 25 % of inorganic N and P and 100 % of inorganic K fertilizers.

Khatal (2008) conducted the incubation study in pot culture and reported that the application of post biomethanated spent wash showed improvement in bulk density and hydraulic conductivity. Soil pH decreased from 8.24 to 8.02 and electrical conductivity increased from 0.423 to 0.475 dSm^{-1}. The increase in organic carbon (0.746per cent) and calcium carbonate (8.60per cent) were also observed at level of application of PBMSW @ 180 m^3 ha^{-1}. The available nutrients *viz.*, N (156 kg ha^{-1}), P (14.25 kg ha^{-1}), K (865 kg ha^{-1}), sulphur (20.08 ppm), sodium (1.28 cmol (p^+) kg^{-1}) and DTPA extractable micronutrients were recorded the highest at 180 m^3 ha^{-1} level of PBMSW.

Deshpande *et al.* (2009) conducted field experiments to assess the effect of PBMSW @ 50,000 liters ha^{-1} on rainfed pearl millet. They reported that, the soil pH was significantly reduced by 0.1 (pH 8.39 to 8.29) unit whereas, the electrical conductivity and exchangeable sodium of soil was increased by 0.05 dSm^{-1} (0.35 to 0.40 dSm^{-1}) and 0.11 cmol (P^+) kg^{-1} [5.47+ 0.5.58 Cmol (P^+) kg], respectively

Durgude *et al.* (2010) observed that application of PBMSW @ 160 m^3 ha^{-1} significantly increased DTPA-Fe (5.17 ppm), Mn (5.81 ppm) and Zn (1.034 ppm) content in soil at 90 days of incubation period in all type of soils i.e. Entisol, Inceptisol and

Vertisol. However, DTPA-Cu content in soil decreased with increasing levels of PBMSW in Entisol, Inceptisol and Vertisol.

2.9 Effect of spent wash bio-compost on biological properties of soil

Studies and published literature on change in biological properties of soil as influenced by application of spent wash is limited and the available literature with respect to impact of spent wash on microbial population is reviewed.

Microorganisms in soil are involved in transformation, recycling and availability of nutrient in soil. The microbial population and their diversity in a soil is largely influenced by soil environment which under influence of application of manures, fertilizers and other agricultural inputs and soil, crop, management practices.

Perucci (1992) studied the microbial biomass in a soil amended with municipal refuse and observed that significant increase in the microbial biomass carbon content.

Goyal *et al.* (1995) reported that, increased soil microbial dyanamics up to 60 days of spent wash application and after that there was reduction in later stage.

Chander *et al.* (1997) observed that, legume cropping systems had higher microbial biomass than that of cereal based cropping systems.

Devrajan *et al.* (1998) studied the effect of municipal refuse on banana crop and reported a reduction in the microbial population at the post harvest stage of banana. The population of Azotobacter was (24.52×10^2 CFU g^{-1}) during 60^{th} day of banana crops.

Mallika *et al.* (2003) evaluated the impact of distillery spent wash on soil enzyme activity and microbial dynamics. Soil treated with spent wash recorded appreciable amount of microbial load and enhanced enzyme activity. The field experiment which was taken up with various levels of spent wash applied as one time land application prior to crop cultivation showed significant increase microbial population *viz.,* bacteria, fungi, Actinomycetes and *Azotobacter*.

Bhasker *et al.* (2005) conducted a field experiment to study effect of integrated use of distillery effluent and fertilizer on soil properties and yield of sugarcane in sandy loam oil and reported that, microbial activities (Bacteria, fungi and actinomycetes) was increased with increase in level of primary treated distillery effluents (1.25 to 6.25 lakh litre ha^{-1})· Among the application of different levels of primary treated distillery effluent, the level of 6.25 lakh litre ha^{-1} has recorded highest microbial properties.

Saliha *et al.* (2005) conducted laboratory incubation experiment to study of the impact of different levels of spent wash *viz.*, 55, 110, and 55 ml kg^{-1} soil. They reported that, the lower levels of spent wash were more effectively than the use of higher level of spent wash. Due to lower levels there is increasing the microbial population of bacteria, fungi, actinomycetes over the control.

Chang *et al.* (2007) studied the effect of different application rates of chemical fertilizers on microbial population and enzymatic activity and reported that soil microbial biomass population of bacteria, fungi, increased significantly in the chemical fertilizer treated soil as compared to compost treated soil.

Gaikwad *et al.* (2009) reported that the application of PBMSW showed significant increase in microbial population *viz.,* bacteria, fungi and also beneficial microbes *viz.*, PSB and *Rhizobium*. Applications of the highest level of PBMSW showed maximum number of microbial colonies, except actinomycetes which were decreased by increasing levels of PBMSW.

Gore (2009) conducted a field experiment to study effect of post biomethanated spent wash on biological properties of sodic soil and yield of sunflower. The maximum microbial activities (bacteria, fungi, Actinomycetes, PSB and *Azotobacter* count) were recorded under conjoint treatment of FYM 5 Mg ha^{-1} + Gypsum @ 50 % GR + RDF. Crop yield as influenced by application of spent wash.

2.10.1 Crop yields as influenced by application of spent wash

Sahai *et al.* (1985) conducted experiment to study the effect of 0.0, 1.0, 2.5, 5, 30, 50, 75 and 100 per cent distillery effluents dilution on germination and growth of *Pea. radiatus* (*Vigna radiata*). They observed that the germination with 0, 5, 15, 30, 30, 50 and 75 per cent effluent was 98,100, 80, 64, 38 and 18 per cent respectively. Increased effluent concentration reduced the speed of germination. The effluent application up to 5 % increased root and shoot length, plant biomass, net primary productivity, chlorophyll content and seed output as compared to the control.

Mukherjee and Sahai (1988) studied the effect of distillery waste 1-100 per cent concentration on seed germination, seedling, seedling establishment and early seedling growth of *Cajanus cajan* L. (var.S-15). The percentage germination, rate of germination, root length and seeding were highest in 5 per cent effluent while shoot length was maximum at 2.5 per cent effluent.

Pande and Sinha (1988) obtained marked increase in dry matter production of cane stalk, fresh weight, height of stalk with10 m^3 vinasse per ha^{-1}. However, sucrose content was enhanced at 35 m^3 vinasse ha^{-1}.

Rajaram and Janardhanan (1988) reported lower concentration of effluent increased seed germination and early seedling growth in cowpea, rice and sorghum while higher concentration retarded not only seed germination but also early seedling growth in all four species investigated. In soybean, percentage germination and early seedlings growth were markedly suppressed by increasing concentration of the effluent.

Rani and Srivastava (1988) conducted a laboratory experiment to study the effect of various concentrations of distillery effluents on the seed germination of wheat. The effluent was highly acidic and rich in dissolved carbon dioxide, total solids, chloride, sulphate and calcium. Germination decreased with increase in effluent concentration. The soaked seeds didn't germinate treated with 50, 75 and 100 per cent effluent.

Jadhav *et al.* (1992) conducted an experiment at Central Sugarcane Research Station, Padegaon on use of spent wash – press mud compost to a*d*sali sugarcane during 1989 to 1992 and reported that, application of 7.5 t ha^{-1} SWC (oven dry basis) with adjusted dose of N, P, K fertilizers (324 :101:129) was beneficial to get higher cane yield (168.96 t ha^{-1}) and CCS (23.03 t ha^{-1}) over other treatments without affecting soil properties.

In the long term field experiment, Shinde *et al.* (1993) revealed that spent wash solids (SWS), farm yard manure (FYM), spent wash pressmud compost were equal in their effect and were found better for increasing sorghum fodder yield, while only press mud proved inferior. The P uptake from press mud and spent wash compost was similar. All the sources increased the uptake of N, P, K and the SWS increased the uptake of K by wheat .Improvement of stability and porosity by PM and FYM application was noted after harvest of wheat taken after sorghum.

Pandey and Soni (1994) conducted a laboratory experiment to evaluate impact of various concentrations (0, 10, 20, 40, 60, 80 and 100 per cent) of distillery effluents on peak value, germination and mean daily germination but had no effect on time taken for germination of *Acacia catechu* and *Dalbergia sissoo* seeds. At low concentration (10 per cent) effluent enhanced the peak value germination and mean daily germination but had no effect on time required for germination compared with control values for the two species.

Zalawadia and Raman (1994) studied effect of distillery waste water with graded fertilizer levels on sorghum yield and soil properties under pot culture. They reported that the grain yield of sorghum was maximum (39 g pot^{-1}), when 100 per cent fertilizer was applied along with 25 times diluted distillery waste water. This was significantly higher than the yield obtained with 100 per cent recommended dose of fertilizer and irrigated with normal water. Stover yield was also significantly influenced by the distillery waste water irrigation with different doses of fertilizer. They also reported that the yield obtained with the 100 per cent dose along with distillery waste water irrigation was maximum and significantly more than the yield obtained with the 100 per cent fertilizer dose and irrigation with normal water. It was further observed that 100 per cent fertilizer application with normal water irrigation yield was statistically same as obtained from 75 per cent recommended dose of fertilizer application with distillery waste water irrigation. Their results concluded that the use of effluent water could save 25 per cent of the fertilizer nutrients for crop production.

Ghugare and Magar (1995) reported that when distillery effluent was diluted 50-75 fold for irrigation cane yield and commercial cane yield was increased significantly.

Pande *et al.* (1995) reported vinasse contains many useful elements and can be profitably recycled to improve soil properties (particularly in reclamation of saline- sodic soils) and increase crop yield while alleviating environmental pollution. Vinasse (2.5 - 3.5 t ha^{-1}, prepared for fertilizer) increased the yield of sugar beet, potatoes and other vegetables by 20 per cent but had adverse effect on legumes and no effect on rice.

Singh and Bahadur (1998) conducted an experiment to utilize distillery effluents having biological oxygen demand of 4620 mg L^{-1} for pre-sowing irrigation and observed that pre-sowing irrigation with effluent of 4620 mg L^{-1} biological oxygen demand had no adverse effect on the germination of maize .The beneficial effects on growth and yield of maize was reported.

Pathak *et al.* (1999) conducted field experiment by using soil amendment with diluted post methanation distillery effluent and reported increase in yield of wheat and rice grown in sequence.

Patil *et al.* (2000) observed an increase in the uptake of nutrients by maize after spent wash application to soil. Significant increase in the uptake of nutrients was recorded by the addition of spent wash at the rate of 50 m^3 ha^{-1} as compared to control. The improvement in fertility status of soil in terms of available N, P and K with the increase in level of spent wash increased.

Rajukannu (2001) reported that the growth and grain yield of rice was increased in sodic soil than the control and gypsum application after application of spent wash.

Ramana *et al.* (2002) conducted a field experiment for two years to study the effect of application of distillery effluents with raw spent wash (RWS), bio-methanated spent wash (BSW), lagoon sludge (LS), recommended NPK + FYM (farmyard manure) and control (no fertilizer and effluent) on maize. The study revealed that among the treatments, the highest grain yield (36.9 q ha^{-1}) was obtained in BSW followed by RWS (32.2 q ha^{-1}) and LS (28.3 q ha^{-1}). The NPK + FYM treatment recorded the highest grain yield (51.8 q ha^{-1}). They proposed that some amount of fertilizer should be supplemented to achieve the full manurial potential of the effluent.

Singh *et al.* (2002) conducted field experiment during kharif season to study the effect of distillery effluent, i.e. biomethanated spent wash (BSW), raw spent wash (RSW), and lagoon sludge (LS) versus recommended NPK + FYM (Farmyard manure) on nutritional quality of groundnut. The distillery effluents did not affect the oil content but increased the seed yield. The BSW produced the highest seed yield (619 kg ha^{-1}) followed by RSW (557 kg ha^{-1}) and LS (472 kg ha^{-1}).

Sukanya and Meli (2002) conducted field investigation to study the effect of conjunctive use of spent wash and water on maize yield treatments with six dilution levels. The results indicated that dilutions levels of 1:5 and 1:10 were found optimum to realize significantly higher grain yield of maize than other treatment combinations.

Hati *et al.* (2003) reported the yield of soybean in all distillery effluent treatment was similar with 100 % NPK + FYM @ 5Mg ha^{-1} but significantly more than control (1.28 Mg ha^{-1}). In wheat highest grain yield was recorded in 100% NPK + FYM @ 4 Mg ha^{-1}, which was at par with 2.5 cm distillery effluent to soybean and 1.25 cm to wheat (1.16 Mg ha^{-1}) 5cm distillery effluent with 5 cm depth to soybean and wheat residual nutrition (3.22 Mg ha^{-1}) and 5 cm distillery effluent to soybean and 2.5 cm to wheat (3.46 Mg ha^{-1}).

Saliha (2003) conducted pot experiment using spent wash at rates equivalent to single application of 0, 25, 50, 125, 250 and 500 m^3 ha^{-1} with and with out organic amendments *viz.*, FYM (12.5 t ha^{-1}), green leaf manure (*Dhaincha* @ 6.25 t ha^{-1}) and biocompost (3 t ha^{-1}). Data revealed that the spent wash > 50 m^3 ha^{-1} was found detrimental for the germination and establishment of green gram in Vertisol, whereas in alfisol even at a rate of 25 m^3 ha^{-1} the spent wash was found to inhibit the germination and growth of green gram. In Vertisol the germination, growth, nutrient contents and yield of green gram was significantly improved with spent wash application at 25 m^3 ha^{-1}.

Sukanya *et al.* (2004) reported that the use of distillery effluent at 1:50 times dilution to wheat recorded significantly higher yield (52.29 q ha^{-1}) than rest of dilution levels. The lowest grain yield (10.59 q ha^{-1}) was recorded in plots irrigated with undiluted effluent. Higher yield at 1:50 times dilution must have supplied additional nutrient helping in better expression of growth (plant height, leaf area index and dry matter production) and yield parameters (productive tillers, grains ear^{-1}, grain weight ear^{-1} and 100 grain weight) while at lower dilution, excessive addition of salts and solids must have caused toxicity and reduction in the growth. Hence, distillery effluents of 1:50 times could be safely used for irrigation to get higher wheat yield.

Kaushik *et al.* (2005) conducted investigation on long term effect of irrigation with post methanation effluent (PME) on sodic soil in the field and short term effect of irrigation with graded levels of PME effluent in the laboratory. They observed that in short term studies, application with 50 per cent PME along with bio-amendment favoured successful germination and improved seedlings growth of pearl millet.

Pragasam and Kannabiran (2006) conducted a field experiment and studied effect of different concentrations of distillery effluents (10, 25, 50, 75 and 100per cent) on the nitrogen, phosphorus and potassium content of *Vigna mungo*. The results revealed that the plant grown in 25% concentration showed more N, P, K contents than those grown in all other concentrations and control. The available N, P, K contents of soil was increased with an increase in effluent concentration upto 100 per cent.

Ranjun (2007) conducted field experiment to study effect of post biomethanated spent wash and spent wash press mud cake on yield of grain and straw of maize. The grain and straw yield of maize varied significantly due to different level of liquid spent wash. The effects were significantly higher over control and was at par with yield obtained at GRD (NPK + 10 t FYM ha^{-1}) indicating that the liquid spent wash without application of NPK fertilizers was equally beneficial for obtaining grain yield of maize as that of NPK + 10 t FYM ha^{-1} (GRD). The grain yield of maize obtained due to spent wash press mud cake levels was also significantly higher over control and as par with that of GRD.

Tripathi *et al.* (2007) conducted field experiment for two consecutive years during 2001-03 to assess effect of distillery effluents under pre sown and post sown irrigation on yields of Rice-Wheat crop sequence. They reported that the dilution of distillery effluent with irrigation water significantly affected the grain yield as well as biomass production of wheat and rice. The highest yields were recorded in plots treated with pre sown distillery effluent @ 20 m^3 ha^{-1} along with 60 kg N ha^{-1} in 2 split doses. However, in post sown distillery effluent applications, the highest grain yield of wheat and rice was obtained in 60 m^3 effluent + 60 kg N ha^{-1}.

Anandakrishnan *et al.* (2008) studied the effect of post biomethanted distillery effluent (PME) on yield of sugarcane in sandy loam and clay loam soil types during 2004-2005. The post bio-methanated spent wash (PME) was applied at different dilutions *viz.,* 1:10, 1:20, 1:30, 1:40 and 1:50 in four splits from 45th day after planting in 40 days interval. The post bio-methanated effluent applied along with irrigation water at different dilutions significantly increased the sugarcane yield over the control and the highest cane yield (121 t ha^{-1}) was noticed in the 1:10 dilution treatment and 147 t ha^{-1} in the 1:20 dilution treatment were obtained in sandy loam and clay loam soil texture, respectively. The commercial cane sugar percentage was increased significantly due to post bio-methanated effluent application.

Bhosale (2008) reported that the grain and straw yields were significantly increased over control due to application of various levels of PBMSW. The grain yield of soybean at all the levels of PBMSW was found significantly superior over control. However, application of 100% N to soybean through PBMSW (40 m^3 ha^{-1}) + P through fertilizer was found most beneficial for obtaining the highest grain and straw yield of soybean with highest benefit cost ratio.

Jawale *et al.* (2010) reported that the magnitude of N, P, and K uptake by pearl millet in the PBMSW treated plot was improved to the tune of 16.4, 24.0 and 16.5 per cent in Entisol and 13.0, 19.0 and 8.0 % in Inceptisol, respectively over the untreated plot.

3. MATERIALS AND METHODS

The present investigation was undertaken during the year 2007-08 at the Department of Soil Science and Agricultural Chemistry, Central Farm of Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra state (India). *Suru* sugarcane (Cv. CO-86032) was planted in the last week of January 2007 under normal and sodic soil conditions. Twelve different bio-composts were prepared on the site of Kolpewadi Co-operative sugar factory, Kopargaon Dist. Ahmednagar (M.S.). The raw spent wash and post bio-methanated spent wash were mixed with different organic sources v*iz.*, baggasse, sugarcane trash, press mud cake, wheat cut straw, pearl millet straw and chickpea straw. Heap method of arobic composting were used for preparation of different bio-composts up to 150 days. The well decomposed bio-composts were prepared and applied as per treatments and replications for the sugarcane crop prior to one month before planting of sugarcane. Total forty eight plots with three replications and sixteen treatments were considered for field study. Details of field study is given in table 10.

Suru sugarcane (Cv. CO-86032) crop was selected for study to assess the effect of spent wash bio-compost on yield, quality and physico-chemical and biological properties of soil. During field experimentation simulteniously N mineralization (Incubation) study was also conducted. The plastic bowls were used for filling the respective surface soil without planting of crop. Soil NH4-N and NO3-N was estimated at an interval of 30, 60, 90 and

120 days of incubation by standard method as indicated in Table 17.

Table 10. Experimental details

Location	Survey No. 50 (PGI, M.P.K.V., Rahuri)
Season	Suru, January
Crop	Sugarcane
Variety	Co-86032
Treatment	Sixteen (16)
Design	Randomized Block Design (RBD)
Replication	Three (3)
Plot size	*Net :* ***Gross :4.50 x 4.00 m²*** ***Net : Net: 2.70 x 3.20 m²***
Spacing	90 cm
Seed rate	30,000 setts ha^{-1}
Date of planting (Normal Soil) (Sodic Soil)	 29/01/2007 30/01/2007
Date of harvesting (Normal Soil) (Sodic Soil)	 30/01/2008 31/0102008

The experimental and treatment details are presented in Tables 11 and layout of experiment is depicted in fig. 1.

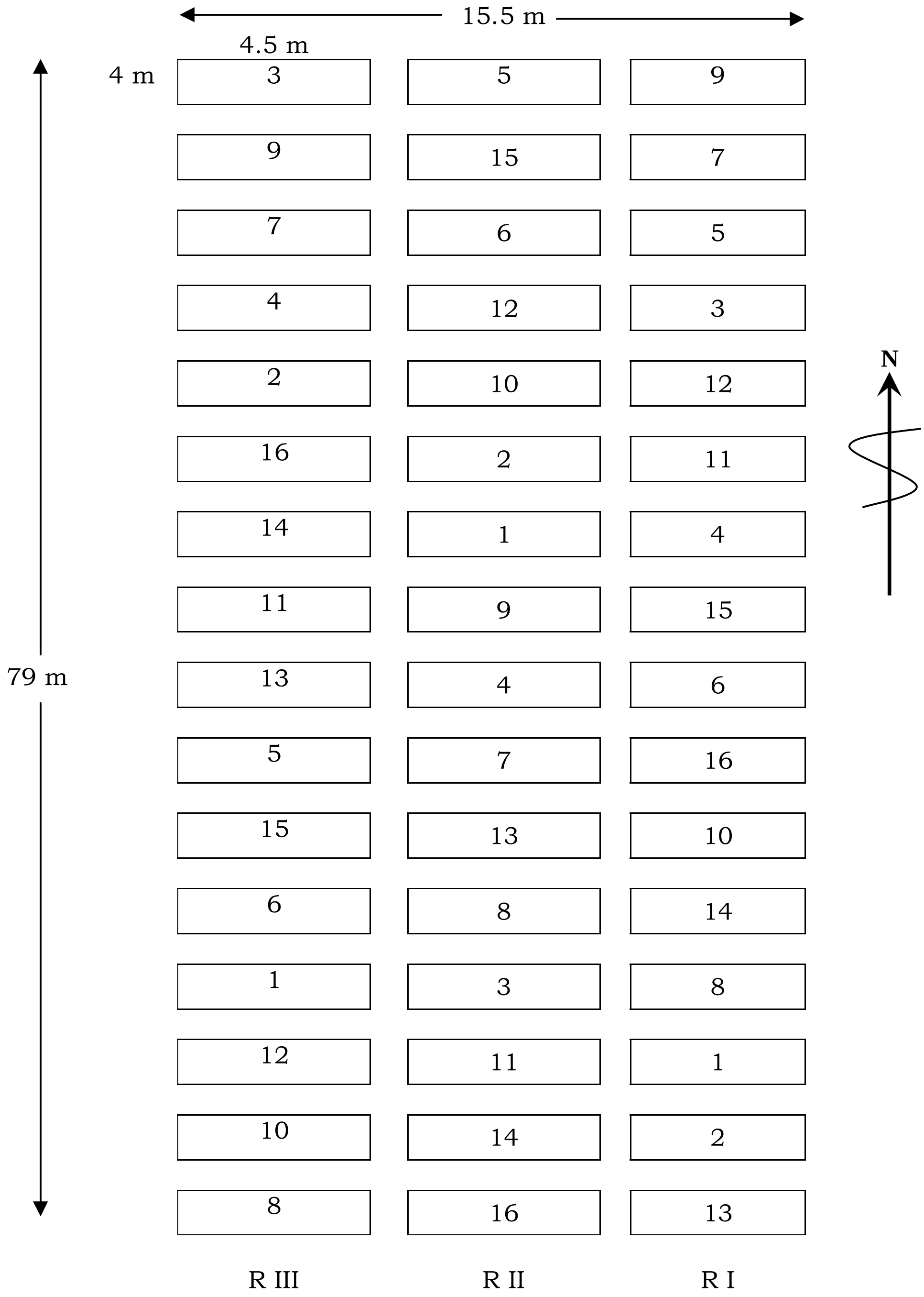

Fig 1. Plan of Layout

Table 11. Treatment details with abbreviations

Sr. No.	Treatment abbreviations	Treatment Detail	Abbre-viations used
1.	T1	Absolute control (No fertilizer /manure)	AC
2.	T2	Raw spent wash + Bagasse compost	RSW + BC
3.	T3	Post bio-methanated spent wash + Bagasse compost	PBSW + BC
4.	T4	Raw spent wash + Sugarcane trash compost	RSW + STC
5.	T5	Post bio-methanated spent wash+ Sugarcane trash compost	PBSW + STC
6.	T6	Raw spent wash + Press mud cake compost	RSW + PMC
7.	T7	Post bio-methanated spent wash + Press mud cake compost	PBSW + PMC
8.	T8	Raw spent wash + Wheat straw compost)	RSW + WSC
9.	T9	Post bio-methanated spent wash+ Wheat straw compost	PBSW + WSC
10.	T10	Raw spent wash + Pearl millet byre waste compost	RSW + PeBWC
11.	T11	Post bio-methanated spent wash + Pearl millet byre waste compost	PBSWC + PeBWC
12.	T12	Raw spent wash + Chickpea Straw compost	RSW + CSC
13.	T13	Post bio-methanated spent wash+ Chickpea Straw compost	PBSW + CSC
14.	T14	Farm Yard Manure	FYM (AST)
15.	T15	Vermicompost	VC (AST)
16.	T16	Recommended Dose of Fertilizer (As per Soil Test)	RDF (AST)

Note: The recommended dose of fertilizers was applied as per soil test value for treatments T_2 to T_{16}.

3.1 Weather condition during the experimental period

The meterological data recorded during the crop growth period of 2007-08 on important weather parameters such as temperature, relative humidity, rainfall, number of rainy days and evaporation etc.are presented in table 12. The weather during the season of 2007-08 was normal for growth of sugarcane crop. The total rainfall was received to the tune of 849.10 mm with 38 rainy days. The mean maximum temperature during the crop growth period was ranged from 23.9 to 41.3 ^{0}C while minimum temperature was ranged from 6.1 to 23.4 ^{0}C. The relative humidity in the morning was ranged from 50 to 95 per cent.

Table 12. Meterological observations for the year 2007-08

Met. week	Temp. (^{0}C)		Relative humidity (%)		Rainfall (mm)	Rainy days (no.)	Evaporation (mm)
	Max.	Min.	7.30 hrs.	14.30 hrs.			
Jan., 2007							
1	28.5	10.1	75	36	0.0	-	2.7
2	29.1	11.3	81	38	0.0	-	2.9
3	30.1	11.0	72	33	0.0	--	3.0
4	31.2	12.2	54	35	0.0	-	3.6
5.	31.9	14.6	59	35	0.0	-	3.7
Feb., 2007							
6	31.5	12.5	51	27	0.0		4.6
7	28.9	12.2	70	32	0.0	-	5.4
8	32.6	14.1	64	23	0.0	-	4.5
9	32.3	12.3	71	26	0.0	-	5.3
March, 2007							
10	33.3	13.3	62	23	0.0	-	6.2
11	33.6	15.2	58	24	0.0	-	6.3
12	35.8	17.3	50	25	0.0	-	7.4
13	37.7	18.3	53	18	0.0	-	7.8

Met. week	**Temp. (⁰C)**		**Relative humidity (%)**		**Rainfall (mm)**	**Rainy days (no.)**	**Evaporation (mm)**
	Max.	**Min.**	**7.30 hrs.**	**14.30 hrs.**			
April, 2007							
14	38.8	18.4	87	19	0.0	-	10.9
15	38.2	18.8	89	22	0.0	-	12.0
16	36.9	20.7	92	30	9.1	1	11.30
17	39.3	19.9	86	19	0.0	-	12.9
18	41.3	22.0	81	20	0.0	-	15.0
May, 2007							
19	40.6	22.0	82	22	0.0	-	15.9
20	38.5	21.7	86	26	83.6	2	12.9
21	37.2	21.7	89	28	0.0	-	11.1
22	36.7	23.2	87	36	44.1	2	9.1
June, 2007							
23	34.4	23.1	92	50	74.1	4	4.8
24	34.8	23.4	91	62	18.8	2	5.7
25	31.7	22.7	94	72	143.2	4	3.9
26	29.5	22.6	94	76	07.8	1	5.0
July, 2007							
27	28.6	23.0	95	74	15.5	3	4.2
28	29.8	22.7	94	71	1.4	-	4.2
29	31.0	21.8	93	72	0.0	-	5.0
30	32.4	22.3	94	64	14.2	1	4.4
31	31.2	22.3	94	66	17.5	3	3.9
August, 2007							
32	30.0	22.4	94	68	3.3	-	4.6
33	30.8	22.0	93	61	4.1	1	5.2
34	31.2	21.6	94	64	44.2	3	4.0
35	29.6	22.0	94	75	125.2	4	2.6
Sept., 2007							
36	29.9	21.9	93	70	84.6	2	3.5
37	29.2	21.9	92	64	22.0	2	4.3
38	29.2	21.5	95	79	70.9	2	3.5

Met. week	Temp. (^{0}C)		Relative humidity (%)		Rainfall (mm)	Rainy days (no.)	Evaporation (mm)
	Max.	Min.	7.30 hrs.	14.30 hrs.			
39	30.4	20.9	93	67	34.6	1	4.4
Oct., 2007							
40	32.2	19.1	92	46	0.0	-	4.3
41	32.7	19.1	86	42	0.0	-	4.2
42	31.9	14.1	78	31	0.0	-	4.9
43	31.8	12.9	85	27	0.0	-	5.4
44	30.6	18.3	91	51	30.9	-	3.7
Nov., 2007							
45	32.8	19.1	92	43	0.0	-	4.1
46	31.0	13.6	88	34	0.0		3.2
47	28.7	7.6	80	38	0.0	-	3.0
48	29.4	9.4	90	49	0.0	-	3.5
Dec., 2007							
49	27.9	9.8	92	38	0.0	-	2.9
50	28.7	12.9	89	45	0.0	-	2.9
51	28.6	12.8	91	45	0.0	-	3.2
52	31.3	10.2	89	36	0.0	-	3.1
Jan., 2008							
1	30.4	10.0	89	34	0.0	-	3.2
2	29.4	9.6	89	35	0.0	-	3.3
3	30.5	9.9	87	33	0.0	-	3.2
4	27.6	6.1	88	29	0.0	-	3.0
5	23.9	6.9	90	30	0.0	-	3.5
TOTAL					**849.10**		**38**

The details regarding the material used and analytical techniques /methods adopted for this present investigation are presented in this chapter.

3.2 Different organic sources

A. Sugarcane trash, baggasse and fresh press mud cake were collected from Kolpewadi Cooperative sugar factory sites

B. Chickpea straw was obtained from Agricultural Research Station Savalivihir, Tal. Kopargaon and Dist. Ahmednagar.

C. Wheat straw was obtained from Main Centre for Cropping System Research Project, MPKV Rahuri.

D. Pearl millet straw was obtained from village Chincholi Gurav, Tal. Sangamner, Dist. Ahmednagar.

E. Farm yard manure and vermicompost were procured from Post Graduate Institute M.P.K.V., Rahuri. Well decomposed bio-compost and manures were dried in shade and sieved material was utilized for experimental purposes.

3.3 Initial soil samples

The representative soil samples (0-30 cm) were collected from the experimental field were dried under shade and processed with wooden mortar and pastle and sieved through 2 mm sieve (nylon netted). The samples were analysed for physical and chemical properties (Table 13).

According to the soil taxonomy, the soils of the experimental field were classified under the order “Vertisol”, comprising of fine montmorillonitic isohyperthermic family of *Typic haplustert* (normal soil) and *Sodic haplustert* (sodic soil). These soils are developed on clayey basaltic alluvium.

Table 13. The physico-chemical properties of experimental soils (initial)

Sr. No.	**Soil parameter**	**Normal soil**	**Sodic soil**
A. Physical properties			
1.	Partical Size Distribution		
	i) Sand (per cent)	18.90	18.63
	ii) Silt (per cent)	25.10	25.60
	iii) Clay (per cent)	56.00	55.77
2.	Textural class	Clay	Clay
3.	Bulk density (Mg m^{-3})	1.40	1.34
4.	Hydraulic conductivity (cm hr^{-1})	0.46	0.14
5.	MWD (mm)	0.55	0.55
6.	Dispersion ratio	18.35	25.38
B. Chemical properties			
1.	pH (1:2.5)	8.25	8.82
2.	EC (dSm^{-1})	0.35	1.12
3.	O.C. (per cent)	0.47	0.37
4.	Avail N (kg ha^{-1})	165.20	153
5.	Avail P (kg ha^{-1})	9.75	7.60
6.	Avail K (kg ha^{-1})	470	390
7.	Fe (mg kg^{-1})	5.25	4.10
8.	Mn (mg kg^{-1})	10.15	9.72
9.	Cu (mg kg^{-1})	3.85	0.88
10.	Zn mg kg^{-1})	0.63	0.39
Exhangeable cations (Cmole(P^{+}) kg^{-1})			
11.	Ca^{2+}	37.50	15.32

Sr. No.	Soil parameter	Normal soil	Sodic soil
12.	Mg^{2+}	20.30	13.22
13.	Na^{+}	4.10	13.50
14.	K^{+}	0.80	0.20
15.	CEC	61.55	45.0
16.	ESP	7.55	20.22
17.	EMP	32.98	26.45
C. Saturation paste extract (me L^{-1}) Cations			
1.	pHs	8.15	8.75
2.	ECe (dSm^{-1})	1.25	2.70
3.	Ca^{2+}	8.66	3.80
4.	Mg^{2+}	7.35	1.72
5.	Na^{+}	10.15	20.25
6.	K^{+}	0.17	0.31
D. Saturation paste extract (me L^{-1}) Anions			
1.	$CO3^{--}$	Absent	Absent
2.	$HCO3^{-}$	4.65	4.52
3.	Cl^{-}	11.40	9.20
4.	$SO4^{-}$	10.32	10.35
5.	SAR	3.62	12.19
E. Biological properties			
1.	Bacteria $X10^{6}$ CFU	22.00	10.22
2.	Fungi $X10^{4}$ CFU	12.50	3.50
3.	Actinomycetes$X10^{5}$ CFU	17.2	3.60

3.4 Seed treatment

Two eye budded setts were soaked in solution containing 300 ml malathion + 10 g of bavistin in 100 L of water for 10 minutes. The same setts were again soaked in solution containing 1.25 kg each of azotobacter, azospirillum, acetobactor and PSB in 100 L of water for 30 minutes and used for planting.

3.5 Method of planting

Preparatory tillage operation was carried out as per the recommended package of practices in order to provide good tilth and weed free condition. In the finely prepared field, ridges and furrows were opened at 90 cm apart for plantation. The experimental field was laid out as per the replications and the treatments.Two eye buded treated setts were used for planting. Dry method of planting was adopted and the setts were placed at centre of furrow by end to end method and covered with dry soil.

3.6 Fertilizer dose applied as RDF (As per soil test)

a. Normal Soil-375:175:70kg ha^{-1} N, P_2O_5 and K_2O respectively

b. Sodic Soil-470:175: 70 kg ha^{-1} N, P_2O_5 and K_2O respectively

1. Soil test values for normal soil (Initial) - 165:9.75:470 kg ha^{-1} N, P and K, respectively
2. Soil test values for sodic soil (Initial)-153:7.60:390 kg ha^{-1} N, P and K, respectively

* There was no deficiency of Fe, Mn, Zn and Cu in *Typic Haplustert* (normal soils). But deficiency of Zn was noticed in *sodic haplustert* (sodic soil). Therefore, 25 kg ha^{-1} zinc sulphate was applied for sugarcane crop at the time of planting.

Table 14. Spilt application of fertilizer doses for sugarcane under normal and sodic soil

Sr. No.	N		P_2O_5	K_2O	$ZnSO_4$
	Normal soil	**Sodic soil**	**Both soils**	**Both Soils**	**Sodic soils**
	--kg ha^{-1}----------------------				
1	37.5	47.0	87.5	35	25
2	150	188	-	-	-
3	37.5	47.0	-	-	-
4	150	188	87.5	35	-

3.6.1 Four splits chemical fertilizer(N) for *suru* sugarcane

a. 10 % N ha^{-1} at time of planting

b. 40 % N ha^{-1} 8 weeks after planting (64 days)

c. 10 % N ha^{-1} 12 weeks after planting (96 days)

d. 40 % N ha^{-1} at the time of final earthing up of cane (135 days)

3.6.2 Chemical fertilizers used for *suru* sugarcane

Commercial grade urea (46.0 N per cent), single super phosphate (16 % P2O5) and muriate of potash (60 % K2O) were used. Application of nitrogen in 4 splits and P_2O_5 and K_2O in 2 splits as per standard package of practices were applied (Table 14). The details of treatment wise quantity of bio-compost applied and chemical fertilizers used in normal and sodic soils for sugarcane is given in Tables 15 and 16.

Table 15. Treatment-wise bio-compost/manure and NPK fertilizers applied to sugarcane in normal soil

Sr. No.	Name of bio-compost	Bio-compost (t ha^{-1})	N*	P_2O_5*	K_2O*
			------------- kg ha^{-1} -----------		
1	AC	-	**No NPK, No manures**		
2	RSW+BC	17.50	375 (815)	175 (1094)	70 (117)
3	PBSW+BC	17.28	375 (815)	175 (1094)	70 (117)
4	RSW+STC	28.57	375 (815)	175 (1094)	70 (117)
5	PBSW+STC	28.00	375 (815)	175 (1094)	70 (117)
6	RSW+PMC	13.00	375 (815)	175 (1094)	70 (117)
7	PBSW+PMC	12.39	375 (815)	175 (1094)	70 (117)
8	RSW+WSC	24.43	375 (815)	175 (1094)	70 (117)
9	PBSW+WSC	23.72	375 (815)	175 (1094)	70 (117)
10	RSW+PeBWC	28.57	375 (815)	175 (1094)	70 (117)
11	PBSWC+PeBWC	29.16	375 (815)	175 (1094)	70 (117)
12	RSW+CSC	16.67	375 (815)	175 (1094)	70 (117)
13	PBSW+CSC	17.28	375 (815)	175 (1094)	70 (117)
14	FYM (AST)	20	375 (815)	175 (1094)	70 (117)
15	VC (AST)	9.09	375 (815)	175 (1094)	70 (117)
16	RDF (AST)	Nil	375 (815)	175 (1094)	70 (117)

* N, P_2O_5 and K_2O content in kg ha^{-1}

Figure in paranthesis indicates the quanity of fertilizers applied

Table 16. Treatment-wise bio-compost/manure and NPK fertilizers applied to sugarcane in sodic soil

Sr. No.	Name of bio-compost	Bio-compost ($t\ ha^{-1}$)	N*	P_2O_5 *	K_2O*
			-------------kg ha^{-1}-----------		
1.	AC	-	**No NPK ,No manures**		
2.	RSW+BC	17.50	450 (978)	175 (1094)	70 (117)
3.	PBSW+BC	17.28	450 (978)	175 (1094)	70 (117)
4.	RSW+STC	28.57	450 (978)	175 (1094)	70 (117)
5.	PBSW+STC	28.00	450 (978)	175 (1094)	70 (117)
6.	RSW+PMC	13.00	450 (978)	175 (1094)	70 (117)
7.	PBSW+PMC	12.39	450 (978)	175 (1094)	70 (117)
8.	RSW+WSC	24.43	450 (978)	175 (1094)	70 (117)
9.	PBSW+WSC	23.72	450 (978)	175 (1094)	70 (117)
10.	RSW+PeBWC	28.57	450 (978)	175 (1094)	70 (117)
11.	PBSWC+PeBWC	29.16	450 (978)	175 (1094)	70 (117)
12.	RSW+CSC	16.67	450 (978)	175(1094)	70 (117)
13.	PBSW+CSC	17.28	450 (978)	175 (1094)	70 (117)
14.	FYM (AST)	20	450 (978)	175 (1094)	70 (117)
15.	VC (AST)	9.09	450 (978)	175 (1094)	70 (117)
16.	RDF (AST)	Nil	450 (978)	175 (1094)	71 (117)

* N, P_2O_5 and K_2O content in kg ha^{-1}

Figure in paranthesis indicates the quanity of fertilizers applied

Laboratory study

3.7.1 Soil analysis

Initial and after harvest of sugarcane, the representative soil samples were analyzed for physical, chemical and microbial count by using standard methods as indicated in Table 17.

3.7.2 Plant study

3.7.2.1 Sugarcane growth study

The sugarcane growth observations were recorded by using tillering ratio, plant height, cane girth and milliable cane.

3.7.2.2 Plant analysis

Treatment wise sugarcane tops and cane samples were collected at harvest, processed and analyzed for total NPK and micronutrient content by using standard methods (Table 17)

3.7.3 Spent wash analysis

Fresh (Non stored) raw spent wash and post bio-methanated spent wash was analysed for different parameters by using of standard methods as indicated in Table 17.,and fresh spent wash utilized for preparation different bio-compost.

3.7.4 Juice quality

The sugarcane juice was extracted from different treatments and were analyzed for brix, purity, sucrose, reducing sugar and CCS.

3.7.5 Yield parameter

Cane, top and CCS yield of sugarcane in t ha^{-1} were recorded.

3.8 Characterization of crop residues

The crop residues *viz.*, baggasse, sugarcane trash,wheat cut straw, pearlmillet byre waste, press mud cake and manures viz., FYM and vermicompost were analysed by using standard metods Table 17.

3.9 Characterization of bio-compost

The different biocomposts, FYM and vermicompost samples were characterised for various chemical properties such as carbon percentage, total nitrogen, phosphorous, potassium, sulphur and micronutrients *viz.,* Fe, Mn, Zn and Cu. Similarly biocompost samples were tested for their quality parameters such as pH, EC, C/N ratio, C:P ratio and C:S ratio, humic acid, fulvic acid content by using standard methods (Table 17).

3.10 Preparation of bio-compost

For preparation of bio-compost the aerobic decomposition process was utilized by adopting heap method of composting. The air dried finely chopped (2-5 cm size) one tonne each crop residues *viz.,* baggasse, sugarcane trash pearl millet straw, wheat straw and chickpea straw were used for preparation of biocompost. The crop residues were mixed well and properly moistened with dung slurry (20 kg cow dung + 500 g per tonne of decomposing culture in 100 L of water. Then as per treatment (Table 17) the respective spent wash i.e. raw and post bio-methanated spent wash was sprayed. The crop residue and fresh (Non stored) spent wash was mixed in proportion of 1:3 (total 3000 L).The spent wash was thoroughly mixed in three splits (1000 L each) at 3 days interval and during application of spent wash the crop residue was turned mechanically. The moisture content was maintained between 50 to 60 %. The three turnings at an interval of one month were given.

The compost samples were drawn at 0,30,60,90 and 120 days of intervals from 30 cm depth at centre of compost heap. The powdered samples were analysed for total carbon, nitrogen, phosphorous, sulphur after drying under shade and oven drying at

70 ^{0}C temperature. The C/N ratio was monitored at each 0, 30, 60, 90 and 120 days of interval.

Table 17. Standard analytical methods used for soil, compost, spent wash and plant analysis

Sr. No.	Particulars	Method	Reference
1.	**Soil analysis**		
a.	**Physical properties**		
i.	Texture	International pipette method	Jackson (1973)
ii.	Bulk density	Clod method	Blake and Hartge (1986)
iii.	Hydraulic conductivity	Constant head method	Black (1965)
iv.	Water stable aggregate	Wet sieving method	Black (1965)
v.	Dispersion ratio	International pipette	Mustafa and Latey (1969)
b.	**Chemical properties**		
i.	pH (1:2.5)	Potentiometry	Jackson (1973)
ii.	EC	Conductometry	Richard (1968)
iii.	Organic Carbon	Walkley and Black, wet oxidation	Nelson and Sommer (1982)
iv.	Available N	Alkaline permanganate	Subbiah and Asija (1956)
v.	Available P	0.5 M $NaHCO_3$ (pH 8.5)Ascorbic acid	Watanabe and Olsen

Sr. No.	Particulars	Method	Reference
			(1965)
vi.	Available K	N N NH_4 OAC	Knudesen *et al.* (1982)
vii.	Available Micronutrients (Fe, Mn, Zn, Cu)	Atomic Absorption Spectrophotometry	Lindsay and Norvell (1978)
viii.	Ca^{2+} and Mg^{2+}	EDTA (Calcon)	Page *et. al* (1982)
ix.	CO_3^{2-} and HCO_3^-	Volumetry	Page *et. al* (1982)
x.	Na^+ and K^+	Flame Photometry	Jackson (1973)
xi.	Cl^-	Titrimetry	Chapman and Pratt (1961)
xii.	SO_4^{2-}	Turbidimetry	Pivinski (1985)
xiii.	CEC	Centrifuge method extractant with 0.4 N NaOAC 0.1 N NaCl (pH 8.2)	Pivinski (1985)
c.	**Saturation paste extract analysis**		
i.	pH	Glass Electrode Potentiometry	Richards (1968)
ii.	EC	Conductometry	Richards (1968)
iii.	ESP	-	Richards (1968)

Sr. No.	Particulars	Method	Reference
iv.	Ca^{2+} and Mg^{2+}	Versanate titration	Richards (1968)
v.	Na^{+} and K^{+}	Flame Photometry	Richards (1968)
vi.	CO_3^{2-} and HCO_3^{-}, Cl^{-}	Volumetry	Richards (1968)
vii.	SO_4^{2-}	Turbidimetry	Chopra and Kanvar (1980)
d.	**Soil incubation study**		
i.	NH_4^{+} - N	2 N KCl extractant, Macro-kjeldhal (MgO)	Keeny and Nelson (1982)
ii.	NO^{-}_{3} N	Devardas alloy	Keeny and Nelson (1982)
e.	**Microbial count**		
i.	Bacteria	Serial Diluation plate method	Halvorson and Ziegler (1933)
ii.	Fungi	Serial Diluation plate method	Halvorson and Ziegler (1933)
iii.	Actinomycetes	Serial Diluation plate method	Halvorson and Ziegler (1933)
2.	**Compost analysis**		

Sr. No.	Particulars	Method	Reference
i.	pH (1:10)	Potentiometry	Jackson, (1973)
ii.	EC (1:10)	Conductometry	Jackson, (1973)
iii.	Organic carbon	Ignition method	Bremner and Mulveney(1982)
iv.	Total N	Macro-kjeldhal	Bremner and Mulveney(1982)
v.	Total P	HNO_3 : $HClO_4$	Olsen and Sommer (1982)
vi.	Total K	Flame photometry (H2O2 +H2SO4)	Chapman and Pratt (1961)
vii.	CEC	1 N BaOAC titrated with 0.05N NaOH	Harada and Inoko (1980)
viii.	H.A./F.A.	0.5 N NaOH WT HCL to pH 1.0 /Amberlite IR-120 resin, liquid was dried below 40 ^oC	Stevenson (1965)
ix.	Total Micronutrient	HNO_3: $HClO_4$ for Mn,Zn, Cu and for Fe (H_2O_2 +H_2SO_4) Atomic Absorption Spectrophotometry (Perkin-Elmer 2380)	Lindsay and Norvell (1978)
3.	**Spent wash analysis**		

Sr. No.	Particulars	Method	Reference
i.	pH	Potentiometry	Jackson(1973)
ii.	Electrical Conductivity	Conductometry	Jackson(1973)
iii.	BOD	Dissolve oxygen method	Franson (1985)
iv.	COD	Open reflux method	Franson (1985)
v.	Nitrogen	Macro kjeldahl	Bremner and Mulvaney (1982)
vi.	Phosphorous	Vanadomolybdate yellow colour	Jackson (1973)
vii.	Potassium	Flame Photometery	Jackson (1973)
viii.	Ca^{2+} and Mg^{2+}	Versanate titration	Jackson (1973)
ix.	Na^{+}	Flame Photometry	Page *et al.*(1982)
x.	CO_3^{2-} and HCO_3^{-} and Cl^{-}	Titrimetry	Richard (1968)
xi.	SO_4^{2-}	Turbidimetry	Pivinski (1985)
4.	**Plant analysis**		
i.	Total Nitrogen	Macro-kjeldhal	Jackson, (1973)
ii.	Total Phosphorus	Vanado molybdate phosphoric acid yellow	Chapman and Pratt,

Sr. No.	Particulars	Method	Reference
		colour	(1961)
iii.	Total Potassium	Flame photometry	Chapman and Pratt, (1961)
iv.	Micro nutrient	Atomic Absorption Spectrophotometry	Zoroski and Burau (1977)
5.	**Sugarcane juice quality parameters**		
i.	Brix	Brix hydrometer with temperature adjusted at 27.5^{o}C	Spencer and Meade (1964)
ii.	Sucrose	Chemitz's table for Horne's dry lead acetate method	Spencer and Meade (1964)
iii.	Reducing sugar	Lane –Eynon General	A.O.A.C. (1975)
iv.	Pol percentage	Horne's dry lead acetate method	Spencer and Meade (1964)

Table 18. Treatment showing different crop residues for preparation of spent wash bio-compast

Sr. No.	Treatment
1.	Raw spent wash + Bagasse (RSW +BC)
2.	Post biomethanated spent wash + Bagasse (PBSW+BC)
3.	Raw spent wash + Sugarcane trash (RSW+STC)
4.	Post biomethanated spent wash+ Sugarcane trash (PBSW+STC)
5.	Raw spent wash + Press mud cake (RSW+PMC)
6.	Post bio-methanated spent wash + Press mud cake (PBSW+PMC)
7.	Raw spent wash + Wheat cut straw (RSW+WSC)
8.	Post bio-methanated spent wash + Wheat cut straw (PBSW+WSC)
9.	Raw spent wash + Pearl millet byre waste (RSW+ PeBWC)
10.	Post bio-methanated spent wash + Pearl millet byre waste (PBSW+ PeBWC)
11.	Raw spent wash + Chickpea straw (RSW+CSC)
12	Post bio-methanated spent wash + Chickpea straw (PBSW+CSC)

3.11 Transportation of bio-compost

Well decomposed air dried bio-composts after 150 days were transported from Kolpewadi co-operative sugar factory Ltd. Kopargaon to the experimental farm of Post Graduate Institute MPKV, Rahuri.in gunny bags separately.

3.12 Nitrogen mineralization study

The nitrogen mineralization (release of NH4 and NO3-N) pattern of treated soils with different bio-composts were studied with the combinations of treatments and replications.

The air dried, sieved (2 mm) 1 kg soil was taken in the plastic bowls and different bio-composts were mixed thoroughly in the soil on the basis of N per cent similar to the field study.

The soil was brought to field capacity moisture with distilled water and thereafter incubated at 25 ^{0} C ± 2 for 120 days. The soil samples were collected at 0,30,60,90 and 120 days of interval, processed and used for NH_4 and NO_3-N content.

The standard analytical methods used for soil, plant, bio-compost and spent wash analysis of different parameters are given in table 17.

3.13 Application of bio-compost

Well decomposed bio-compost was weighed as per treatments (table 15 and 16). The respective bio-composts were broadcasted and mixed thoroughly prior to one month before planting of suru sugarcane.

3.14 Irrigation to sugarcane

The source of irrigation water was Mula canal.The water quality was excellent (C1S1) category. The irrigation was scheduled as per the requirement of crop for both the soils. First irrigation was given immediately after dry planting of sugarcane. In all 15 and 12 irrigations were required suru sugarcane grown under normal and sodic soils, respectively.

The details of cultural operations carried out for suru sugarcane is presented in Table 19.

Table 19. The details of cultural operations carried out during the period of investigation

Sr. No.	Cultural operation	Date of operations	
		Normal soil	**Sodic Soil**
1.	Ploughing	25/11/2006	28/11/2006
2.	Harrowng	26/11/2006	29/11/2006
3.	Discing	27/11/2006	30/11/2006
4.	Preparation of irrigation layout	1/01/2007	1/01/2007
5.	Application of bio-compost	2/01/2007	2/01/2007
6.	Preparation of ridges and furrows irrigation layout	22/01/2007	25/01/2007
7.	Planting of sugarcane	29/01/2007	30/01/2007
8.	Application of fertilizers	29/01/2007 2/03/2007 3/05/2007 16/06/2007	30/01/2007 02/03/2007 3/5/2007 16/06/2007
9.	Hand weeding	10/02/2007 1/03/2007 30/042007 14/6/2007 16/9/2007	12/02/2007 2/03/2007 30/04/2007 15/06/2007 17/9/2007
10.	Number of irrigations	29/01/2007 16/02/2007 10/03/2007 3/04/2007 30/04/2007 25/05/2007 16/06/2007 14/07/2007 17/08/2007 20/09/2007 16/10/2007 8/11/2007 28/11/2007 22/12/2007 20/01/2008	30/01/2007 17/02/2007 11/03/2007 4/04/2007 2/05/2007 30/05/2007 27/06/2007 10/08/2007 22/09/2007 18/10/2007 30/11/2007 24/12/2007
11.	Light earthing up	7/03/2007	8/03/2007
12.	Final earthing up	14/06/2007	15/06/2007
13.	Harvesting of sugarcane	30/01/2008	31/01/2008

3.15 Sampling technique

3.15.1 Soil sampling

In order to study the effects of distillery effluents (spent wash) through biocompost on pertinent physico-chemical properties of soil, the initial soil samples were collected, before planting of sugarcane crop and before application of manure and fertilizer. At harvest the soil samples were also collected at 0-30 cm depth from three randomly selected spots and composite representative sample was obtained from each treatment and replication wise for soil analysis

The soil samples obtained were dried in a shade. The soil samples were pounded by mortar and pastle and then passed through 2 mm sieve for chemical properties *viz.*, pH, EC, available N, P and K. For determination of organic carbon 0.5 mm sieved sample was used.

3.15.2 Plant sampling

The morphological observations such as number of tillers, tillering ratio at 60 and 120 days, milliable canes, cane height and girth of cane were also recorded at harvest. Five clumps of cane were selected randomly from each treatment from all three replications and were cut to the ground level and fresh weights were recorded. The treatment and replicationwise fresh cane top and cane samples were separated. Fresh samples were initially air dried and then kept in an oven drying at 62 ^{0}C and dry weights were recorded. The canes and cane top were chopped, mixed thoroughly and a composite sample was used for determination of dry matter. A part of sample was dried, ground and about 20 g of representative sample from the powdered

Material was preserved and used for estimation of total N, P and K, micronutrients like Fe, Mn, Cu and Zn content to study the concentration and uptake of nutrients. The details of the standard methods used estimation of chemical parameters are given in Table 17.

3.16 Growth observations

3.16.1 Germination percentage

The germination count of sugarcane was taken one month after planting. The germination percentage was 95 in normal soil where as 90 in sodic soil. Gap filling was done in both the experiments.

3.16.2 Number of tillers per plant

The number of tillers was counted at 60 and 120 days which were calculated by following formula.

$$\text{Tillering ratio} = \frac{\text{Total number of shoots - number of cane of mother cane}}{\text{Number of mother canes}}$$

The total number of tillers from selected five clumps were counted and recorded from each plot at 120 days after planting.

3.16.3 Plant height

The plant height was measured from the base of shoot to base of fully opened last leaf of the shoot. The periodical height was measured at regular intervals *viz.*, 60^{th}, 120^{th}, 180^{th} day after planting and at harvest.Total height and millable cane height were recorded.

3.16.4 Number of millable canes

Millable canes from each treatment were counted at harvest of sugarcane crop.

3.16.5 Girth of cane

The circumference of the top, middle and bottom internodes of each cane was measured and five readings were averaged to get the girth of cane.

3.17 Yield of cane and green tops

The canes were harvested from individual plot. After detrashing and removal of tops from plants the weight of millable canes and tops as per treatments were recorded and reported as yield of sugarcane and green tops in tonnes ha^{-1}.

3.18 Nutrient uptake

The uptake of major nutrients like N, P, K was worked out by multiplying dry matter accumulation and with concentration of N,P and K at harvest by using the following formula

$$\text{Uptake of nutrient (kg ha}^{-1}\text{)} = \frac{\text{Total dry matter x Concentration of nutrient}}{100}$$

3.19 Cane juice sampling

Fresh juice samples were utilized for quality parameters Canes were cleaned by removing dry leaves and cane top. Cane juice was extracted with the help of steel crusher. About one litre of fresh cane juice was extracted in clean plastic cans from each treatment, for quality studies.

3.19.1 Cane juice quality studies

Juice was analysed in the laboratory for various quality parameters *viz.*, brix, POL, sucrose, purity, reducing and non reducing sugar content. The methods adopted for juice analysis are given in Table 17.

3.19.2 Brix

The brix values (total soluble solids) in the juice sample was estimated by using brix hydrometer and expressed in terms of brix (corrected) after making calibration for temperature. After crushing, the filtered juice sample was taken in a 500 ml measuring cylinder and filled to the top level of the cylinder and recorded the reading of brix hydrometer in the juice. The recorded observations were calibrated for juice temperature from chart. The treatment and replication wise brix (T.S.S.) observations were recorded.

3.19.3 POL

The POL (Sucrose content) values were determined by the polorimeter after clarifying the juice by using lead acetate. The sucrose content of the juice was expressed in per cent using Schmitz's conversion table.

3.19.4 Purity

Purity is the ratio of sucrose content of the juice (POL) to the total soluble solids [Brix (^0C)]. It was worked out and expressed in per cent.

$$\text{Purity (per cent)} = \frac{\text{POL (Sucrose) per cent}}{\text{Brix } (^0C)} \times 100$$

3.19.5 Commercial cane sugar (CCS)

The CCS percentage was worked out from the POL (Sucrose) percentage using formula given in Schimmits conversion table.

CCS % = {S-(B-S)X 0.4} X 0.74 *

Where, S = Sucrose percent

B = Corrected brix

* Crushing factors of sugarcane juice crusher.

3.19.6 Commercial cane sugar yield

The yield of commercial cane sugar was calculated based on commercial cane sugar percentage and the cane yield and expressed in tones ha^{-1}.

$$\text{CCS yield (t ha}^{-1}) = \frac{\text{Cane yield (t ha}^{-1})}{100} \times \text{CCS (per cent)}$$

3.20 Methods

3.20.1 Methods for soil analysis

3.20.1.1 Fertility stataus

The soil samples were analysed for pH, EC, organic carbon, available N, P, K, S, exchangeable cations CEC, ESP, EMP as well as saturated paste extract analysis in respect of cations and anions, pHs, ECe, DTPA extractable micronutrients and physical properties by adopting the standard methods as indicated in table 17.

3.21 Statistical analysis

The experimental data were subjected to statistical analysis for assessing the effects due to treatments by Randomized Block Design outlined by Panse and Sukhatme (1985).

4. RESULTS AND DISCUSSION

The investigation was under taken on "Utilization of spent wash through bio-compost for *suru* sugarcane under normal and sodic soil condition." Field trial was conducted at the Post Graduate Institute Research Farm, Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, Dist. Ahmednagar (M.S.) during the year 2007-08. The study was undertaken for utilization of spent wash through bio-compost prepared from different crop residues *viz*; sugarcane trash, baggasse, press mud cake, wheat cut straw, pearl millet straw and chickpea straw. These crop residues/organic sources were selected for preparation of different bio-compost through raw and post bio-methanated spent wash. Well decomposed bio-compost prepared from raw and post bio-methanated spent wash with different crop residues/organic sources were applied for *suru* (Seasonal) sugarcane as per the treatments presented in Table 12.

These different crop residues/organic sources as well as FYM, and vermicompost were analyzed for its nutrient content *viz.,* total nitrogen, phosphorus, potassium, organic carbon, micronutrients cations and C/N ratio before preparation of bio-compost. Similarly the well decomposed bio-compost and manures were also analyzed and characterized for N,P,K, micronutrients, C:N, C:P, C:S ratio, humic and fulvic acid content. Characterization of different crop residues/organic sources was done and their results are presented in the Table 20.

Table 20. Macro, micro-nutrients and C:N ratio of different crop residues and manures

Sr. No.	Crop residues	Organic carbon	Macronutrient -------per cent---			C:N ratio	Micronutrients (mg kg^{-1})			
			N	P	K		Fe	Mn	Cu	Zn
1.	Baggasse	39.40	0.49	0.22	0.68	80.41	370	119	42	105
2.	Sugar cane trash	50.00	0.40	0.17	0.45	125.00	365	112	35	92
3.	Press mud cake	40.00	0.80	1.30	0.85	50.00	3308	348	110	251
4.	Wheat cut straw	33.09	0.47	0.15	0.41	70.40	167	380	40	35
5.	Pearl millet straw	46.94	0.39	0.18	1.30	120.36	355	102	45	20
6.	Chickpea straw	36.18	0.90	0.24	0.59	40.20	395	192	59	121
7.	FYM	16.12	0.80	0.51	0.95	20.15	9850	683	85	118
8.	Vermicompost	28.91	1.58	0.58	1.22	18.30	925	412	55	181

4.1 Total nutrient content and C:N ratio of different crop residues

Among the different crop residues, the organic carbon content ranged from 33.09 per cent (wheat cut straw) to 50 per cent (sugarcane trash) followed by pearl millet straw (46.94 per cent). Among the manures, FYM showed very low content of organic carbon (16.12 per cent) followed by vermicompost (28.91 per cent). Among the all organic sources, chickpea straw showed highest content in nitrogen (0.90 per cent) followed by press mud cake (0.80 per cent). Lowest nitrogen was noticed in pearl millet straw (0.39 per cent) followed by sugarcane trash

(0.40 per cent). Among the manures, vermicompost contain highest nitrogen (1.58 per cent) as compared to FYM (0.80 per cent).

The highest P content was observed in press mud cake (1.30 per cent). Whereas other crop residues contain low phosphorus which was ranged from 0.15 (wheat cut straw) to 0.24 per cent (chickpea straw).

The total K content was highest in pearl millet straw (1.30 per cent) followed by press mud cake (0.85 per cent). In manures vermicompost contain higher K (1.22 per cent) as compared to FYM (0.95 per cent). Wheat cut straw contain lowest K (0.41 per cent) followed by sugarcane trash (0.45 per cent). The highest C: N ratio was observed in sugarcane trash (125:1) followed by pearl millet straw (120:1) and baggasse (80.4:1). The chickpea straw showed lowest C:N ratio (40:1) followed by press mud cake (50:1). The chickpea straw showed lowest C:N ratio (40:1).

Mohan Sing (1991), Singh *et al.* (1995), Rao and Tarfdar (1998), Manna *et al.* (2000) and Ganguly and Singh (2004) reported similar observations for different crop residues in respect of content of NPK and C/N ratio.

4.2 Total micronutrient content of different crop residues

The data presented in Table 20 in respect of micro-nutrient content indicated that the iron content was highest in FYM (9850 mg kg^{-1}) followed by press mud cake (3308 mg kg^{-1}). The low iron content was observed in wheat straw (167 mg kg^{-1}).

The Mn content was ranged from 102 to 683 mg kg^{-1} in pearl millet and FYM, respectively. The lowest content of copper was observed in sugarcane trash (35 mg kg^{-1}) whereas highest copper content was noticed in press mud cake (110 mg kg^{-1}). The zinc content in different crop residues was ranged from 20 (Pearl millet straw) to 251 mg kg^{-1}

(press mud cake). These results indicated that, there was a wide variation in micronutrient content

in different crop residues and organic manures. Comparatively, the highest iron, mangenese, copper and zinc was reported in press mud cake followed by FYM and vermicompost.

4.3 Characterization of spent wash

The data in respect of characterization of raw and post bio-methanated spent wash is presented in table 21.

a. Raw spent wash

The raw spent wash was obtained from Kolpewadi Co-operative Sugar Factory, Kopergaon, Dist. Ahemdnagar (M.S.) showed very dark coffee brown colour with very unpleasant odour. The pH was very low (4.2) with very high electrical conductivity (19.85 dSm^{-1}), biological oxygen demand (32000 mg L^{-1}) and chemical oxygen demand (91000 mg L^{-1}) values. Total solids were also high (95000 mg L^{-1}). The total NPK content was 1100, 30.85 and 8800 mg L^{-1}, respectively. The calcium content was to the tune of 1890 mgL^{-1}, sodium and magnesium was also present with high concentration to the tune of 850 and 1035 mg L^{-1}, respectively. The raw spent wash contained chloride and sulphate to the tune of 4200 and 5400 mg L^{-1}, respectively. The micro-nutrients *viz.*, Fe, Mn, Zn and Cu were present to the tune of 250, 10.35, 4.20 and 0.75 mg L^{-1}, respectively.

b. Post bio-methanated spent wash

The post bio-methanated spent wash was also obtained from Kolpewadi Co-operative Sugar Factory, Kopergaon, Dist. Ahemdnagar (M.S.) was neutral in reaction (pH 7.2) had the EC(12.55 dSm^{-1}), BOD (4400 mg L^{-1}) and COD (25000 mg L^{-1}), total solids (73500 mg L^{-1}) and colour parameters were considerably reduced as compared to raw spent wash .The total NPK content was to the tune of 850, 10.25 and 6000 mg L^{-1}, respectively. The content of Na^+ decreased considerable (180 mg L^{-1}) as compared to raw spent wash (850 mg L^{-1}). The chloride and sulphate was to the tune of 3520 and 2200 mg L^{-1}, respectively. The micro nutrients concentration specifically content of iron (25.30 mg kg^{-1}) was also reduced as compared to raw spent wash (250 mg kg^{-1}). The results of characterization of both the spent wash are in conformity with the findings of Patil (1994), Jadhav (1997), Mallika *et al.* (2003), Haroon and Bose (2004), Bhalerao *et al.* (2006) and Ranjun (2007).

Table 21. Characterization of raw (RSW) and post bio-methanated spent wash (PBSW)

Sr. No.	**Parameter**	**RSW**	**PBSW**
1.	Colour	Dark coffee brown	Dark raddish
2.	Odour	Very unpleasant	Unpleasant
3.	pH	4.2	7.2
4.	EC (dS m^{-1})	19.85	12.55
5.	Org. Carbon (per cent)	33.60	26.85
6.	BOD (mg L^{-1})	32000	4400
7.	COD (mg L^{-1})	91000	25000
8.	Total Solid (mg L^{-1})	95000	73500
9.	Moisture (per cent)	90	93
10.	Ash (per cent)	3.5	2.0
11.	Total N (mg L^{-1})	1100	850
12.	Total P (mg L^{-1})	30.85	10.25
13	Total K (mg L^{-1})	8800	6000
14.	Calcium (mg L^{-1})	1890	1200
15.	Sodium (mg L^{-1})	850	180
16.	Magnesium (mg L^{-1})	1035	720

17.	Chlorides (mg L^{-1})	4200	3520
18.	Sulphate (mg L^{-1})	5400	2200
19.	Iron (mg L^{-1})	250	25.30
20.	Manganese (mg L^{-1})	10.35	9.70
21.	Zinc (mg L^{-1})	4.20	1.30
22.	Copper (mg L^{-1})	0.75	0.52

4.4 Characterization of different bio-compost at an interval of 30, 60, 90 and 120 days

The different organic sources with raw and post bio-methanated spent wash were used for preparation of bio-compost. These bio-composts were analysed at an interval of 30, 60, 90 and 120 days of decomposition. The detailed characterization at different intervals is presented in tables 22, 23, 24 and 25 .

4.4.1 pH of bio-compost

The pH of bio-compost at 30 days was ranged from 6.15 to 6.99 which was steadily increased at 60, 90 and 120 days. In general, pH at 30 days was slightly acidic which was slightly increased to neutral range at 120 days of period of decomposition. The use of raw spent wash showed comparatively lower values of pH than post bio-methanated spent wash compost of their respective crop residues. The use of raw spent wash with PMC showed comparatively lowest value of pH i.e. 6.15, 6.4, 6.69 at the interval of 30, 60 and 90 days, respectively of decomposition thereafter it became neutral. The different bio-compost prepared from spent wash at 120 days showed overall neutral to slightly alkaline reaction (7.1 to 7.5). The pH of raw spent wash bio-compost was less as compared to the post bio-methanated spent wash. It might be due to the acidic nature of raw spent wash than the post bio methanated spent wash.

4.4.2 Total soluble salt in bio-compost

The electrical conductivity was also steadily increased from 30, 60, 90 and 120 days in all the bio-compost prepared from different crop residues. The use of raw spent wash bio-compost with pearlmillet straw showed higher EC at 30 days (3.55 dSm^{-1})

Table 22. Chemical properties of bio-compost at 30 days of decomposition (% on oven dry basis)

Sr. No.	Treatment	pH (1:10)	EC (1:10) (dSm-1)	C	N	P	K	S	C:N	C:P	C:S
				-------------------Per cent				--------------	-------------ratio----------		
1.	RSW+BC	6.35	3.50	26.20	0.65	0.28	0.58	0.35	40.31	93.57	68.95
2.	PBSW+BC	6.90	3.20	27.10	0.62	0.30	0.59	0.34	43.71	90.33	73.28
3.	RSW+STC	6.45	3.45	27.20	0.46	0.20	0.41	0.23	59.13	136.00	108.80
4.	PBSW+STC	6.98	3.25	27.15	0.47	0.21	0.43	0.24	57.77	129.29	113.13
5.	RSW+PMC	6.15	3.48	30.22	0.78	0.60	0.82	0.45	38.74	50.37	67.16
6.	PBSW+PMC	6.92	3.30	30.15	0.80	0.62	0.84	0.47	37.69	48.63	64.15
7.	RSW+WSC	6.50	3.45	25.10	0.67	0.26	0.5	0.39	37.46	96.54	64.36
8.	PBSW+WSC	6.94	3.10	24.65	0.67	0.25	0.53	0.40	36.79	98.60	61.63
9.	RSW+PeBWC	6.59	3.55	25.55	0.45	0.18	0.42	0.38	56.78	141.94	67.24
10.	PBSWC+PeBWC	6.99	3.12	25.45	0.46	0.19	0.44	0.40	55.33	133.95	63.63
11.	RSW+CSC	6.55	3.40	30.00	0.79	0.22	0.6	0.55	37.97	136.36	54.55
12.	PBSW+CSC	6.98	3.18	30.15	0.76	0.24	0.63	0.55	39.67	125.63	54.82

Table 23. Chemical properties of bio-compost at 60 days of decomposition (% on oven dry basis)

Sr. No.	Treatment	pH (1:10)	EC (dSm^{-1})	C	N	P	K	S	C:N	C:P	C:S
				--------------------Per cent---------------					----------ratio-----------		
1.	RSW+BC	6.45	3.90	22.27	0.67	0.31	0.64	0.38	33.24	71.84	58.61
2.	PBSW+BC	7.00	3.70	23.04	0.64	0.33	0.65	0.36	36.00	69.82	64.00
3.	RSW+STC	6.65	3.65	23.12	0.47	0.22	0.45	0.25	49.19	105.09	92.48
4.	PBSW+STC	7.05	3.45	23.08	0.48	0.23	0.47	0.24	48.08	100.35	96.17
5.	RSW+PMC	6.40	3.70	25.69	0.80	0.66	0.90	0.55	32.11	38.92	46.71
6.	PBSW+PMC	7.08	3.51	25.63	0.82	0.68	0.92	0.56	31.26	37.69	45.77
7.	RSW+WSC	6.72	3.68	21.34	0.69	0.29	0.55	0.41	30.93	73.59	52.05
8.	PBSW+WSC	7.0	3.31	20.95	0.69	0.28	0.58	0.42	30.36	74.82	49.88
9.	RSW+PeBWC	6.72	3.69	21.72	0.46	0.20	0.46	0.40	47.22	108.60	54.30
10.	PBSWC+PeBWC	7.05	3.23	21.63	0.47	0.21	0.48	0.41	46.02	103.00	52.76
11.	RSW+CSC	6.75	3.62	25.50	0.81	0.24	0.66	0.60	31.48	106.25	42.50
12.	PBSW+CSC	7.10	3.41	25.63	0.78	0.26	0.69	0.62	32.86	98.58	41.34

Table 24. Chemical properties of bio-compost at 90 days of decomposition (% on oven dry basis)

Sr. No.	Treatment	pH (1:10)	EC (dSm^{-1})	C	N	P	K	S	C:N	C:P	C:S	H.A	F.A.
				-------------------Per cent----------					------------ratio------			-Per cent--	
1.	RSW+BC	6.70	4.1	18.93	0.69	0.34	0.70	0.38	27.43	55.68	49.82	28	12.5
2.	PBSW+BC	7.15	3.95	19.58	0.66	0.36	0.71	0.36	29.67	54.39	54.39	30	13.7
3.	RSW+STC	6.88	3.79	19.65	0.48	0.24	0.50	0.25	40.94	81.88	78.60	24	10.4
4.	PBSW+STC	7.15	3.68	19.62	0.49	0.25	0.52	0.24	40.04	78.48	81.75	25	11.6
5.	RSW+PMC	6.69	3.92	21.83	0.83	0.73	0.99	0.82	26.30	29.90	26.62	35	13.55
6.	PBSW+PMC	7.18	3.63	21.78	0.85	0.75	1.02	0.83	25.62	29.04	26.24	38	14.6
7.	RSW+WSC	6.95	3.79	18.13	0.71	0.31	0.61	0.40	25.54	58.48	45.33	23	11.44
8.	PBSW+WSC	7.13	3.51	17.81	0.71	0.30	0.64	0.42	25.08	59.37	42.40	22	10.58
9.	RSW+PeBWC	6.93	3.90	18.46	0.47	0.22	0.51	0.40	39.28	83.91	46.15	25	10.56
10.	PBSWC+ PeBWC	7.16	3.45	18.39	0.48	0.23	0.53	0.41	38.31	79.96	44.85	26	10.75
11.	RSW+CSC	6.98	3.83	21.68	0.82	0.27	0.73	0.61	26.44	80.30	35.54	37	14.66
12.	PBSW+CSC	7.19	3.62	21.78	0.81	0.29	0.76	0.63	26.89	75.10	34.57	35	15.68

Table 25. Chemical properties of bio-compost at 120 days of decomposition (% on oven dry basis)

Sr. No.	Treatment	pH (1:10)	EC (dSm^{-1})	C	N	P	K	S	C:N	C:P	C:S	H.A	F.A.
				------------------Per cent----------					-----------ratio------			-Per cent--	
1.	RSW+BC	7.2	4.20	16.09	0.8	0.37	0.77	0.39	20.11	43.49	41.26	6.9	21
2.	PBSW+BC	7.4	4.0	16.64	0.82	0.4	0.79	0.38	20.29	41.60	43.79	7.3	22.5
3.	RSW+STC	7.2	3.95	16.70	0.49	0.27	0.55	0.26	34.08	61.85	64.23	6.9	21.5
4.	PBSW+STC	7.5	3.88	16.67	0.5	0.28	0.57	0.25	33.34	59.54	66.68	7.1	23.0
5.	RSW+PMC	7.2	4.12	18.56	1.08	0.80	1.09	0.82	17.19	23.20	22.63	7.9	25.30
6.	PBSW+PMC	7.1	3.85	18.52	1.13	0.83	1.12	0.82	16.39	22.31	22.59	8.6	26.30
7.	RSW+WSC	7.1	3.95	15.41	0.84	0.35	0.67	0.41	18.35	44.03	37.59	7.2	21.70
8.	PBSW+WSC	7.5	3.72	15.14	0.87	0.33	0.71	0.41	17.40	45.88	36.93	6.3	22.60
9.	RSW+PeBWC	7.2	4.10	15.69	0.49	0.24	0.56	0.4	32.02	65.38	39.23	7.5	22.30
10.	PBSWC+ PeBWC	7.4	3.68	15.63	0.49	0.25	0.59	0.41	31.90	62.52	38.12	7.3	23.80
11.	RSW+CSC	7.1	4.05	18.42	0.84	0.29	0.80	0.62	21.93	63.52	29.71	6.9	21.90
12.	PBSW+CSC	7.5	3.85	18.52	0.83	0.32	0.84	0.63	22.31	57.88	29.40	6.3	22.80

and 60 days (3.69 dSm^{-1}), 90 days (3.9 dSm^{-1}) and 120 days (4.1 dSm^{-1}). In general, the use of raw spent wash in crop residue composting showed higher soluble salt content over the use of post bio-methanated spent wash. The use of post bio-methanated spent wash in chickpea straw compost showed lowest EC value at 30 days (3.18 dSm^{-1}) and 60 days (3.41 dSm^{-1}) as compared to other bio-compost of different crop residues. The highest EC at 120 days was noticed in bio-compost prepared from raw spent wash + baggasse (4.2 dSm^{-1}) followed by PMC (4.12 dSm^{-1}).

The soluble salt content at 120 days of different bio-compost was ranged from 3.68 (dSm^{-1}) (PBSW + pearl millet straw) to 4.20 (dSm^{-1}) (RSW + Baggasse). In general, bio-compost prepared from raw spent wash showed higher values of EC over the use of post bio-methanated spent wash in respective crop residues. EC of raw spent wash bio-compost was higher than that of post bio-methanated spent wash bio-compost It might be due to higher content of soluble salts in raw spent wash as compared to the post bio-methanated bio-compost.

4.4.3 Organic 'C' content

The use of raw as well as post bio-methanated spent wash in PMC and chickpea straw showed comparatively higher organic 'C' content at 30, 60, 90 and 120 days of decomposition as compared with other crop residues. The lower content of organic 'C' was noticed in wheat straw bio-compost at 30, 60, 90 and 120 days of decomposition under the use of raw and post bio-methanated spent wash. The organic 'C' content steadily declined from 30 days to 120 days in all the bio-composts during decomposition. The organic 'C' content ranged from 15.14 (PBSW + Wheat cut straw compost) to 18.56 (Raw spent wash + PMC compost) per cent at 120 days of composting.

Similar trend in loss of organic carbon, variation in pH and EC was also reported by Mathur *et al.* (1980), Shinde and Rote (1983), Asija *et al.* (1984), Bhanwase *et al.* (1994), Manna *et al.* (2000) for different composts prepared from crop residues.

4.4.4 Total nitrogen content

The total nitrogen content in bio-compost was ranged from 0.49 per cent to (RSW + STC, RSW + PeBWE and PBMSW + PeBWC) to 1.13 per cent (PBSW + PMC). As maturity of the compost increased from 30 to 120 days the content of nitrogen was increased. The PBSW + PMC showed comparatively higher nitrogen content as compared with other bio-compost.

4.4.5 Total phosphorous content

The total Phosphorus content in bio-compost was ranged from 0.24 per cent (RSW +PeBWE) to 0.83 per cent (PBSW + PMC bio-compost). Total P content was steadily increased with the stage of maturity.

4.4.6 Total potassium content

The total Potassium content in biocompost was ranged from 0.55 per cent (RSW +STC) to 1.12 per cent (PBSW + PMC bio-compost). Total K content was steadily increased with the stage of maturity.

4.4.7 Total sulphur

The total sulphur content in bio-compost was ranged from 0.24 per cent (PBMSW +STC) to 0.81 per cent (PBSW + PMC bio-compost). The sulphur content was steadily increased from 30 and 60 days and after 90 days then it was stabilized.

4.4.8 C: N ratio of compost

The C : N ratio at 30 days ranged from 36.79 (PBSW + WSC) to 59.13 (RSW + Sugarcane trash). The C : N ratio of all crop residues was continuously declined at 30, 60, 90 and 120 days of decomposition. The lower values of C:N ratio was noticed in bio-compost prepared from raw as well as post bio-methanated spent wash with press mud (16.39) followed by wheat cut straw(17.40) and baggasse (21.93). The bio-compost prepared from sugarcane trash and pearl millet straw showed comparatively higher C:N ratio than other crop residues.

The lowest C:N ratio was noticed in PBSW + PMC compost (16.39) followed by RSW + PMC (17.18). It might be due to the fast mineralization of PMC and higher per cent of nitrogen in PMC as compared to remaining bio-compost. As nitrogen percentage increases the C/N ratio decreases. The highest C:N ratio of bio-compost was noticed in RSW + sugarcane trash compost (34.09) followed by PBMSW + PeBWC (32.56). It might be due to the initial wide C/N ratio, slow mineralization and less nitrogen content of sugarcane trash and peralmillet straw.

4.4.9 C: P ratio

The press mud compost showed comparatively lowest C:P ratios than other crop residues. The C:P ratio of different bio-compost ranged from 50.37 (RSW + PMC) to 141.94 (RSW + PeBWC) at 30 days of decomposition, which steadily decreased at 60, 90 and 120 days. The lowest C:P ratio at 120 days was noticed in bio-compost prepared from post bio-methanated spent wash + PMC (22.31) and highest C:P ratio was reported in raw spent wash + pearl millet byre waste straw (65.38).

4.4.10 C: S ratio

The press mud compost showed comparatively lowest C:S ratios than other crop residues. The C:S ratio also steadily decreased from 30, 60, 90 and 120 days of decomposition. At 120 days of composting the C:S ratio ranged from 22.86 (PBSW + PMC) to 69.46 (PBSW + S.cane trash). The lower values of C: S ratio was observed in bio-compost prepared from raw as well as post bio-methanated spent wash with press mud cake followed by chickpea straw. The NPK and S content was increased steadily from 30 to 120 days of decomposition could be due to loss of organic carbon and increase in microbial biomass during the process of decomposition. The reduction in C:N, C:P and C:S during the process of decomposition was also reported by Talashikar *et al.* (1999), Shinde and Rote (1983), Mathur et al.(1980) and Bhanwase *et al.* (1994).

4.4.11 Humic and Fulvic acid content

The humic acid content was ranged from 22 (PBSW + WCS) to 37 per cent (RSW + CSC) and fulvic acid from 10.40 (RSW + STC) to 15.68 per cent (PBSW + CSC) at 90 days of decomposition stage. The humic acid content was higher than fulvic acid at 90 days (Table 24). However, the humic acid content at 120 days was ranged from 6.3 (PBSW + WCS and CSC) to 8.6 (PBSW + PMC) where as fulvic acid ranged from 21.0 (RSW + Bagasse) to 26.30 per cent (PBSW + PMC). The values of humic acid were comparatively lower than fulvic acid at 120 days (table 25).

In general, the post bio-methanated spent wash + press mud compost showed highest content of humic acid (8.6 per cent) and fulvic acid (26.30 per cent) followed by press mud bio-compost prepared from raw spent wash. However, at 120 days of decomposition stage the fulvic acid content increased drastically than humic acid. Singh and Amberger (1990) also reported similar observation.

4.4.12 Micronutrient content in different bio-composts

The data presented in Table 26 in respect of total micronutrient cations in bio-compost indicated that the iron content was ranged from 1652 (RSW + pearl millet straw) to 4435 mg kg^{-1} (RSW + Press mud cake). The highest content of mangenese (482 mg kg^{-1}) was noticed in bio-compost prepared from raw spent wash + Press mud cake whereas lowest mangenese content (192 mg kg^{-1}) observed in bio-compost prepared from post bio-methanated spent wash + wheat cut straw compost. The copper content ranged from 36 (PBSW + pearl millet straw) to 75 mg kg^{-1} (RSW + STC). The highest content of zinc was noticed in bio-compost prepared from sugarcane trash with raw spent wash (210 mg kg^{-1}), whereas lowest zinc content was noticed in PBSW + pearl millet straw compost (64 mg kg^{-1}).

Table 26.Micronutrient content in different bio-composts before planting

Sr. No.	Bio-compost	Fe	Mn	Cu	Zn
		-------------------(mg kg^{-1})-----------------------			
1.	RSW+BC	2920	220	42	72
2.	PBSW+BC	2895	195	39	68
3.	RSW+STC	2765	310	75	210
4.	PBSW+STC	2610	287	60	192
5.	RSW+PMC	4435	482	68	98
6.	PBSW+PMC	4260	390	52	87
7.	RSW+WSC	2530	222	40	70
8.	PBSW+WSC	2415	192	38	67
9.	RSW+PeBWC	1652	210	39	68
10.	PBSW+PeBWC	2542	195	36	64
11.	RSW+CSC	3317	478	59	86
12.	PBSW+CSC	3040	365	47	78

4.5 Effect of spent wash bio-compost application on sugarcane growth

The data in respect of effect of spent wash bio-compost on growth parameters of sugarcane are presented in tables 27 and 28.

4.5.1 Effect on tillering ratio

A. Normal soil

The effect of application of spent wash bio-compost on tillering ratio at 60 days did not influence significantly. However, the treatment effect was significant at 120 days of tillering.

The application of spent wash compost showed significantly higher tillering ratio over control, RDF, FYM, and vermicompost. The tillering ratio at 120 days was ranged from 3.50 (AC) to 3.91 (PBSW + PMC). The highest tillering ratio (3.91) was observed under treatment PBSW + PMC.

B. Sodic Soil

The application of spent wash compost significantly increased tillering ratio at 120 days over control, RDF, FYM and vermicompost. The tillering ratio under sodic soil was ranged from 2.80 (vermicompost) to 3.39 (PBSW + CSC).The effects of application of spent wash bio-compost prepared from chickpea straw and press mud cake were comparable in respect of tillering ratio. The effect of either raw spent wash or post bio-methanated spent wash was found comparable.

The use of spent wash for sugarcane enhanced the tillering ratio and growth of sugarcane was also reported by Ghugare (1994).

Table 27. Effect of spent wash bio-compost application on growth characters of *Suru* sugarcane in normal soil

Sr. No.	Treatment	Tillering ratio		Cane height	Girth	No. of millable canes (000 ha^{-1})
		60	120	---------(cm)------		
		---------DAS---------		-------------At harvest------------		
1	AC	2.30	3.50	222.33	9.10	68.92
2	RSW+BC	2.44	3.71	251.00	9.14	71.47
3	PBSW+BC	2.49	3.74	258.67	9.17	73.23
4	RSW+STC	2.60	3.70	264.67	9.19	74.33
5	PBSW+STC	2.65	3.71	266.33	9.24	75.70
6	RSW+PMC	2.72	3.84	270.33	9.42	80.35
7	PBSW+PMC	2.76	3.91	277.33	9.45	81.43
8	RSW+WSC	2.60	3.71	262.00	9.31	78.43
9	PBSW+WSC	2.63	3.72	268.67	9.34	76.52
10	RSW+PeBWC	2.45	3.70	259.00	9.37	77.73
11	PBSWC+PeBWC	2.50	3.71	266.00	9.39	77.50
12	RSW+CSC	2.73	3.74	267.67	9.43	80.22
13	PBSW+CSC	2.75	3.70	269.67	9.45	80.48
14	FYM (AST)	2.34	3.58	265.00	9.14	75.57
15	VC (AST)	2.38	3.60	257.33	9.18	78.48
16	RDF (AST)	2.40	3.56	227.33	9.16	69.35
	SE ±	0.45	0.81	0.76	0.45	0.01
	CD at 5 %	NS	2.33	NS	NS	0.03

Table 28. Effect of spent wash bio-compost application on growth characters of *Suru* sugarcane in sodic soil

Sr. No.	Treatment	Tillering ratio		Cane height	Girth	No. of millable canes (000 ha^{-1})
		60	120	-----------(cm)---		
		---------DAS------		-------------At harvest--------		
1	AC	1.80	2.87	212.67	8.07	58.40
2	RSW+BC	2.33	3.20	242.00	8.67	59.31
3	PBSW+BC	2.33	3.27	244.33	8.68	60.85
4	RSW+STC	2.30	3.29	241.00	8.69	61.26
5	PBSW+STC	2.33	3.27	242.33	8.75	62.85
6	RSW+PMC	2.37	3.30	244.00	8.93	66.67
7	PBSW+PMC	2.43	3.37	248.33	8.96	66.64
8	RSW+WSC	2.37	3.30	246.00	8.83	65.43
9	PBSW+WSC	2.33	3.27	242.00	8.85	66.70
10	RSW+PeBWC	2.30	3.31	242.67	8.87	65.01
11	PBSWC+PeBWC	2.33	3.30	242.67	8.89	66.87
12	RSW+CSC	2.33	3.32	246.00	8.95	66.37
13	PBSW+CSC	2.43	3.39	250.00	8.95	66.92
14	FYM (AST)	1.93	2.93	240.67	8.65	61.74
15	VC (AST)	2.10	2.80	241.00	8.69	61.00
16	RDF (AST)	2.17	3.05	218.33	8.67	59.81
	SE ±	1.87	0.87	0.19	0.32	0.01
	CD at 5 %	NS	2.51	0.53	0.92	0.03

4.5.2 Effect on cane height and girth of sugarcane

A. Normal soil

The application of spent wash bio-compost prepared from different crop residues did not significantly influenced cane height as well as cane girth (table 27).

B. Sodic soil

The application of PBSW + CSC showed highest cane height (250 cm) followed by PBSW + PMC (248.33 cm) but highest cane girth (8.96 cm) was observed in PBSW + PMC followed by PBSW + CSC (8.95 cm) over control (table 28).

4.5.3 Effect on millable cane

A. Normal soil

The application of PBSW + PMC showed significantly highest number of millable canes (81.43 $x10^3$ ha^{-1}) over RDF, FYM and vermicompost treatments. The number of millable canes ranged from 68.92 (A.C.) to 81.43 $x10^3$ ha^{-1}(PBSW + PMC) (Table 27).In general , the use of bio-compost prepared from raw spent wash showed significantly lower millable canes over the use of bio-compost prepared from post bio-methanated spent wash except bio-compost prepared from wheat straw and pearl millet byre waste. Thus the use of bio-compost prepared from raw spent wash or PBMSW with different crop residues showed significantly higher number of millable canes over control and RDF.

B. Sodic soil

The number of millable canes under sodic soil condition ranged from 58.40 $x10^3$ ha^{-1} (A.C.) to 66.92 $x10^3$ ha^{-1} (PBSW + CSC). The application of spent wash bio-compost significantly increased number of millable canes over control and RDF. Use of raw spent wash compost significantly decreased the number of millable canes over the use of bio-compost prepared from post bio-methanated spent wash. The use of PBSW + CSC significantly increased the number of millable canes as compared to other bio-compost and manures. The number of millable canes increased due to application of spent wash compost was also reported by Ghugare (1994).

In general, the effect of application of post bio-methanated compost and chickpea compost comparatively showed better growth parameters in respect of tillering ratio, cane height, cane girth and number of millable canes under normal and sodic soil conditions. This could be due to improvement in physical, chemical and biological properties of soil which reflected in enhancing the soil fertility status and bio-availability of plant nutrients to sugarcane for its growth.

4.6 Effect of spent wash bio-compost on yield of sugarcane

The data in respect of effect of application of spent wash bio-compost on cane and top yield of sugarcane in normal and sodic soil is presented in table 29.

4.6.1 Cane yield of suru sugarcane

A. Normal soil

The data presented in Table 29 and fig 2 showed that the application of spent wash bio-compost significantly increased the cane yield over control and RDF. The cane yield ranged from 63.90 (A.C.) to 109 t ha^{-1} (PBSW +PMC) .The use of bio-compost prepared from PBSW with press mud cake(109 t ha^{-1}) and chickpea straw(101.00 t ha-1) showed significantly higher cane yield over the use of bio-compost prepared from raw spent wash. The press mud compost prepared from post bio-methanated spent wash significantly gave highest cane yield (109 t ha^{-1}) followed by use of raw spent wash with press mud cake and use of PBSW + CSC (101 t ha^{-1}). The use of raw spent wash showed comparatively lower cane yield (103.9 t ha^{-1}) and (96.59 t ha^{-1}) for press mud cake and chickpea compost respectively as compared to bio-compost prepared from PBSW (Fig. 2). However, similar trend was not observed for bio-compost prepared from other crop residues.

Table 29. Effect of spent wash bio-compost application on cane and top yield (t ha^{-1}) of *suru* sugarcane

Sr. No.	**Treatment**	**Normal soil**		**Sodic soil**	
		Cane yield	**Top yield**	**Cane yield**	**Top yield**
1	AC	63.90	5.75	51.22	4.89
2	RSW+BC	85.22	7.67	68.17	6.52
3	PBSW+BC	87.28	7.86	69.83	6.68
4	RSW+STC	81.07	7.47	64.86	6.20
5	PBSW+STC	82.84	7.46	66.27	6.34
6	RSW+PMC	103.94	9.35	83.15	7.95
7	PBSW+PMC	109.00	9.81	87.20	8.34
8	RSW+WSC	84.59	7.58	67.67	6.47
9	PBSW+WSC	84.78	7.63	67.83	6.49
10	RSW+PeBWC	84.87	7.64	67.70	6.50
11	PBSWC+PeBWC	84.94	7.64	67.95	6.49
12	RSW+CSC	96.59	8.69	77.34	7.39
13	PBSW+CSC	101.00	9.09	80.80	7.73
14	FYM (AST)	81.47	7.33	65.18	6.23
15	VC (AST)	82.47	7.42	65.19	6.24
16	RDF (AST)	75.35	6.78	60.28	5.71
	SE ±	1.24	0.11	0.99	0.10
	CD at 5 %	3.57	0.32	2.86	0.27

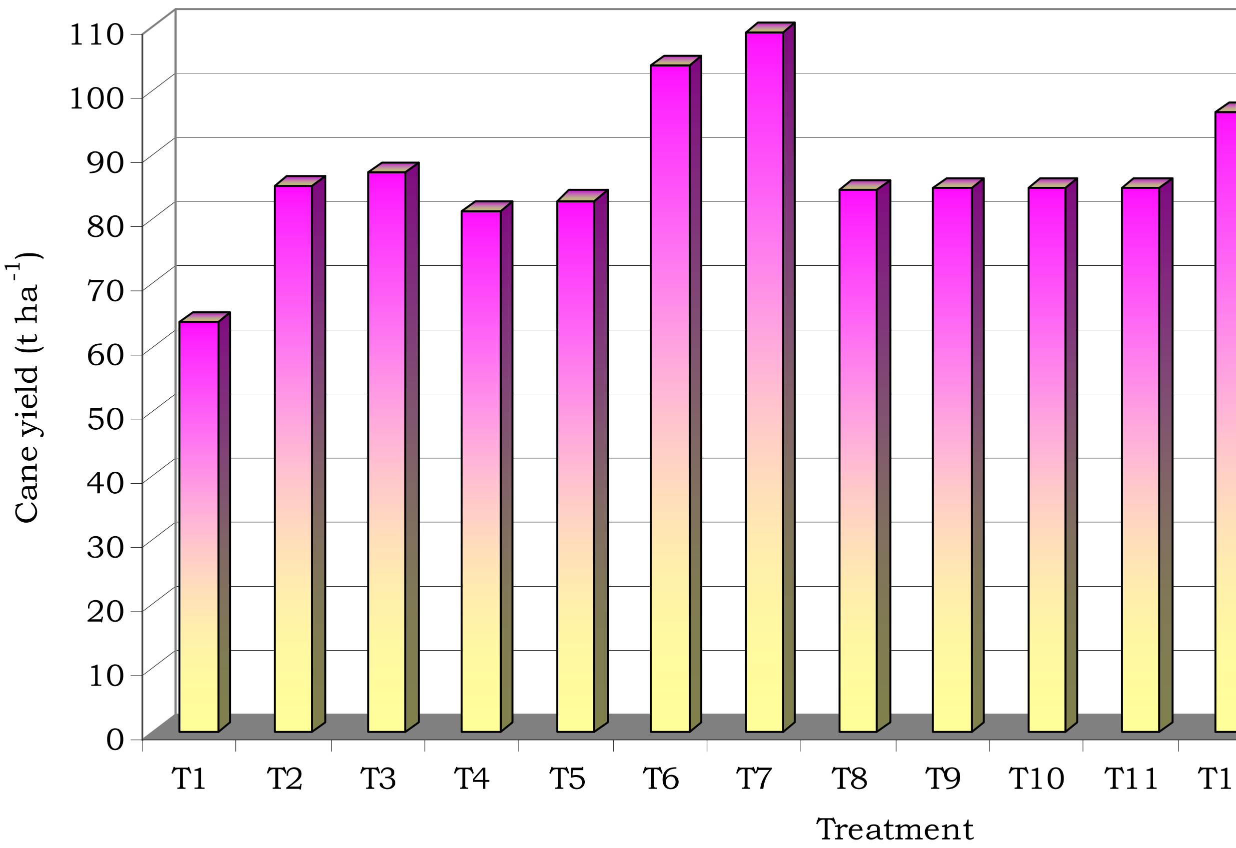

Fig. 2. Effect of spent wash bio-compost application on cane y

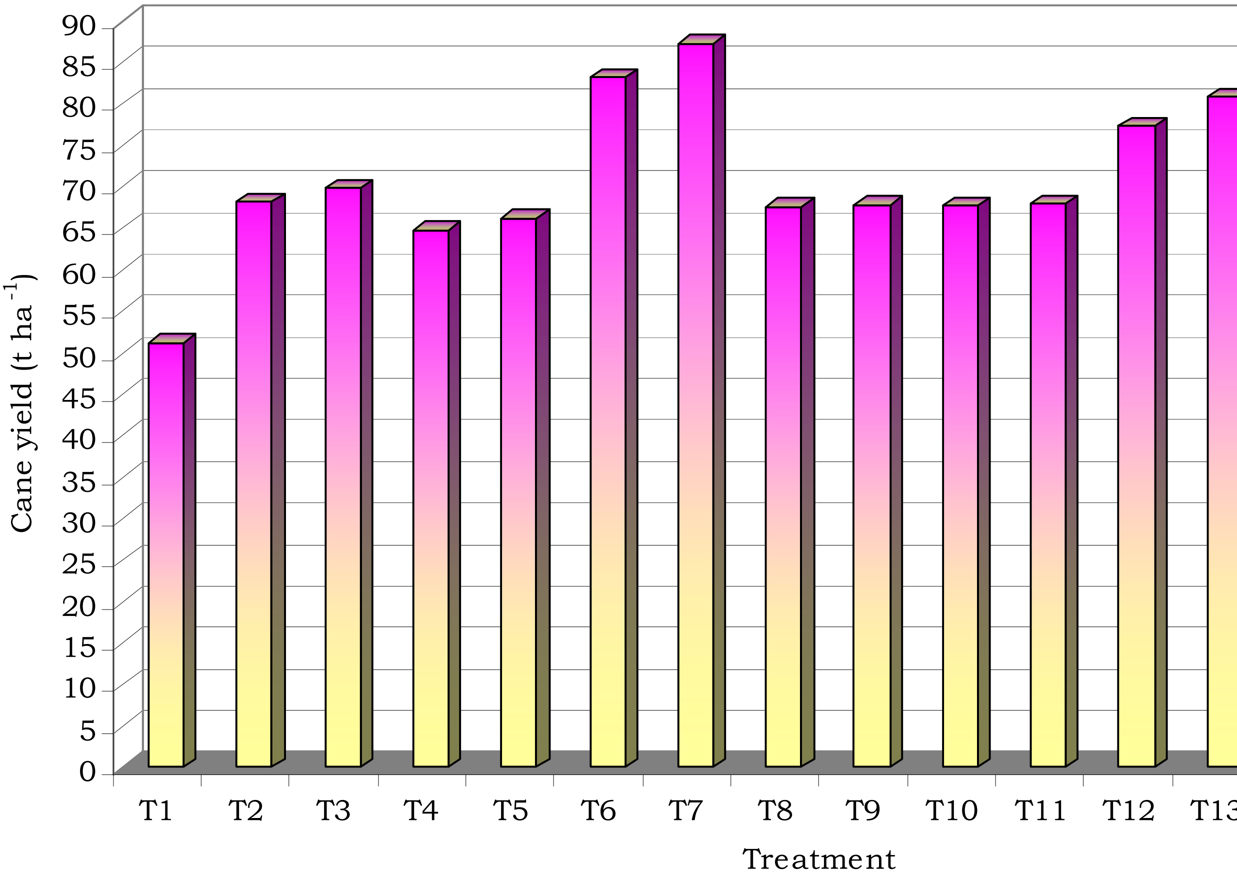

Fig. 3. Effect of spent wash bio-compost application on cane yield i

B. Sodic Soil

The data on cane yield as influenced by use of different bio-compost prepared from raw and post bio-methanated spent wash are depicted in Table 29 (Fig. 3). The cane yield was significantly superior in all bio-compost treated plots over control and RDF. The cane yield obtained from compost prepared from press mud cake, chickpea and bagasse by use of raw and post bio-methanated spent wash showed significantly higher cane yield over use of FYM and vermicompost. Among the all treatments, use of post bio-methanated + PMC compost showed highest cane yield (87.20 t ha^{-1}) over raw spent wash (83.15 t ha^{-1}). Similar trend was also noticed for bio-compost prepared from chickpea straw, where the use of raw spent wash showed comparatively lower cane yield (77.34 t ha^{-1}) over the use of post bio-methanated spent wash (80.80 t ha^{-1}). However, the effect of raw spent wash and post bio-methanated spent wash was at par in the other crop residues viz., baggasse, wheat straw, sugarcane trash and pearl millet straw etc.

4.6.2 Effect of spent wash bio-compost on cane top yield of sugarcane

A. Normal soil

The data in respect of sugarcane top yield are presented in Table 29. The significantly higher top yield was reported in treatment PBSW + PMC (9.81 t ha^{-1}) followed by RSW + PMC (9.35 t ha^{-1}) and PBSW + CSC (9.09 t ha^{-1}) over the use of FYM and vermicompost. The use of bio-compost either prepared from RSW or PBSW did not show its effect on top yield of sugarcane.

B. Sodic Soil

The top yield of sugarcane ranged from 4.89 to 8.34 t ha^{-1}. The bio-compost prepared from post bio-methanated spent wash and PMC showed significantly highest top yield (8.34 t ha^{-1}) followed by raw spent wash + PMC bio-compost (7.95 t ha^{-1}) and post bio-methanated spent wash + chickpea straw bio-compost (7.73 t ha^{-1}). These treatments were significantly superior over FYM and vermicompost. The other crop residue bio-compost showed comparable effects as that of FYM and vermicompost under sodic soil condition.

Thus, the yield parameters clearly indicate that the significant response for increase in yields due to application of bio-compost prepared from spent wash. Among the treatments the use of PBSW+PMC showed significantly highest cane and top yield under normal and sodic soil condition over RDF, FYM and vermicompost indicating superiority of use of spent wash bio-compost prepared from PBSW + PMC for enhancing bio-availability of plant nutrients and improvement in physico-chemical and biological and enzymatic activities in pedo environment which ultimately reflected in enhancing the soil fertility, the nutrient uptake and growth parameters of sugarcane under normal and sodic soil. The application of spent wash/ spent wash compost improved the crop yields, physico-chemical, biological properties and enzymatic activities also reported by Dongale and Sawant (1978) for sorghum, Pande and Sinha (1988) for cane stalk yield, Jadhav *et al.* (1992) for *adsali* sugarcane, Shinde *et al.* (1993), Zalawadia and Raman (1994) for sorghum yield, and Rajukannu (2001) for rice in sodic soil.

Therefore, these results are in accordance with the use of spent wash bio-compost/ spent wash also showed ameliorating effects on sodic soil were also reported by several workers Mahimaraja and Nanthi (2004), Sen (2003) and Kaushik *et al.* (2005).

4.7 Effects of application of spent wash bio-compost on juice quality of sugaracane

The data on effect of application of spent wash bio-compost on brix, purity, CCS, sucrose, reducing sugar under normal and sodic soil condition are depicted in Tables 30 and 31.

4.7.1 Juice quality

A. Normal soil

The effect of spent wash bio-compost showed non significant influence on brix, (per cent), CCS (per cent) and sucrose content of sugarcane juice. Whereas reducing sugar and CCS yield was significantly increased due to application of bio-compost over RDF and control. The highest CCS yield (14.37 t ha^{-1}) was recorded in PBSW + PMC followed by PBSW+ CSC (13.16 t ha^{-1}) (Fig. 4). The rest of the bio-compost treatments showed comparable CCS yield over FYM and vermicompost.

The purity percentage was ranged from 89.70 (RSW + BC) to 95.11% (RSW + STC). Whereas reducing sugar content ranged from 0.19 per cent to 0.35 per cent. The PBSW + PMC showed highest reducing sugar content (0.35 per cent). The lowest content of reducing sugar (0.19 per cent) was observed in control.

B. Sodic soil

The purity per cent was ranged from 86.21 (PBSW +BC) to 93.81 % (PBSW + WSC). Whereas, CCS percentage ranged from

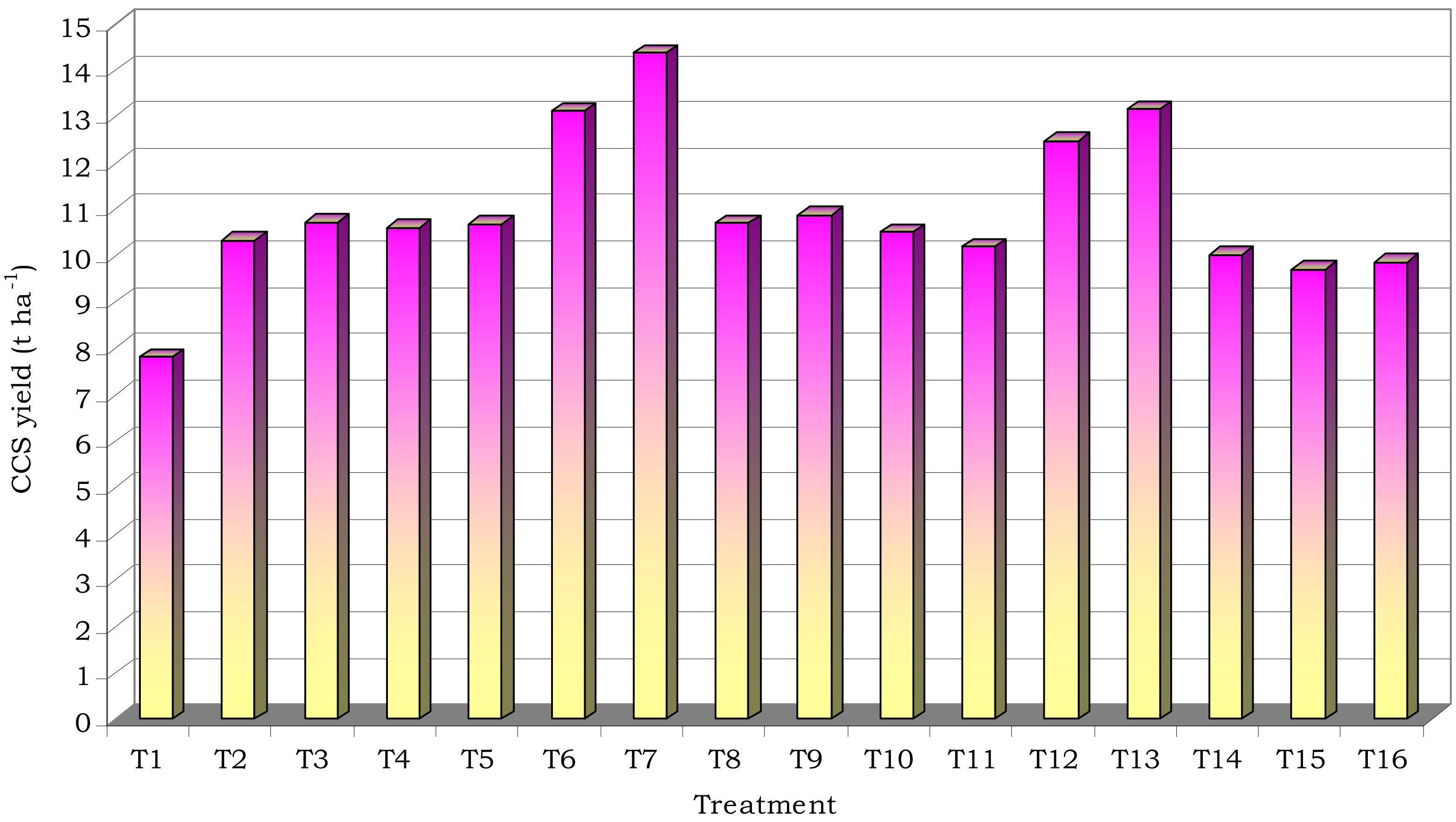

Fig. 4. Effect of spent wash bio-compost application on CCS yield (t ha^{-1}) under normal soil

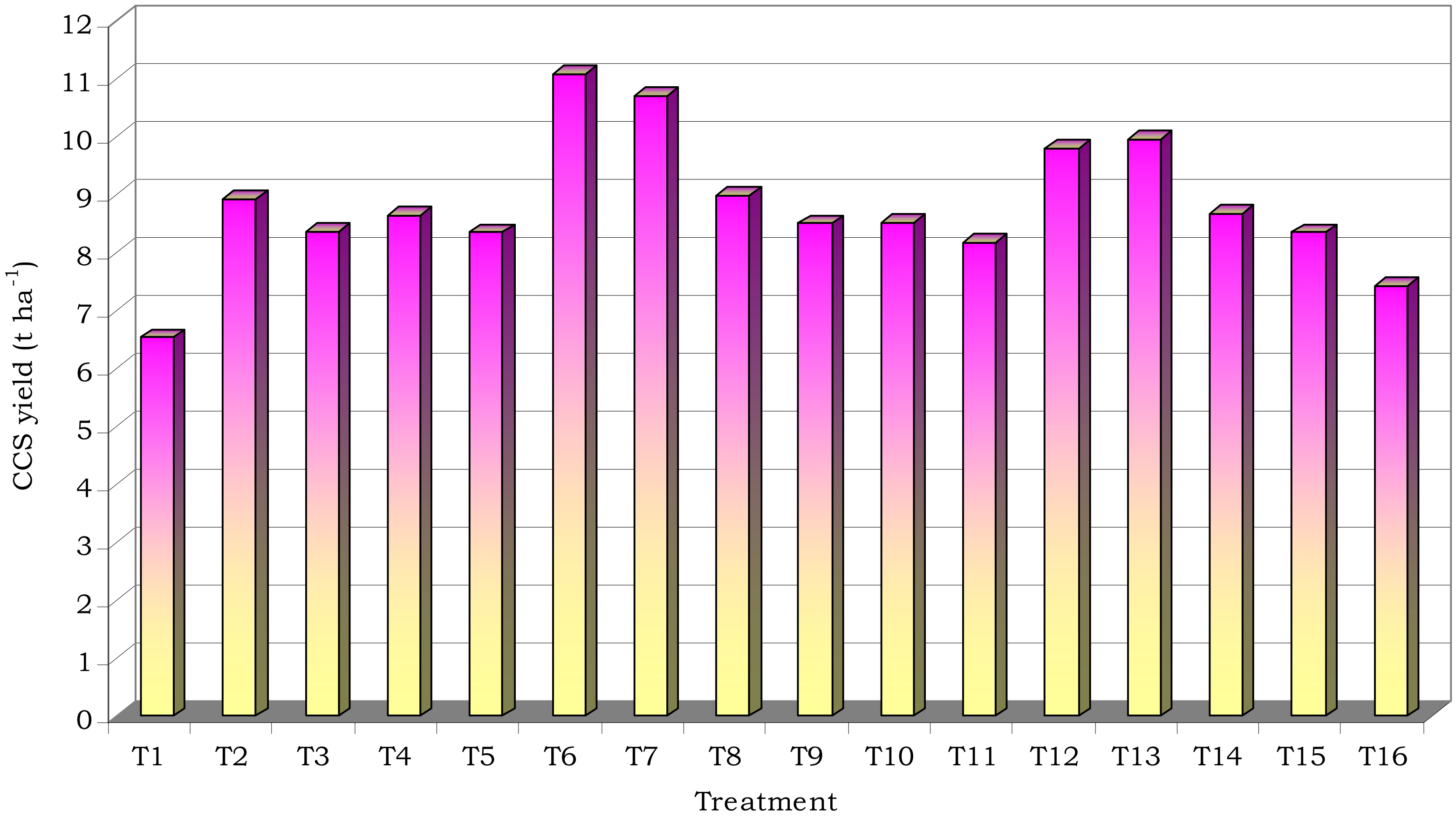

Fig. 5. Effect of spent wash bio-compost application on CCS yield (t ha^{-1}) under sodic soil

11.99 % (PBSW + BC) to 13.44 % (RSW + STC). The highest content of sucrose was noticed in treatment RSW + WSC (20.94 per cent).The CCS yield was ranged from 6.53 (control) to 11.08 t ha^{-1} (RSW + PMC) followed by (PBSW + PMC) 10.69 t ha^{-1} · The bio-compost prepared from press mud cake and chickpea straw showed comparatively higher CCS yield over RDF, FYM and vermicompost (Fig. 5).

These results are in conformity with the findings of Ghugare (1994) and Bhalerao *et al.* (2006),where the application of spent wash/ spent wash compost increased in CCS percent and CCS yield (t ha^{-1}) which could be attributed due to increase in yield, sucrose content, P and K availability, uptake over control and RDF.

Table 30. Effect of spent wash bio-compost application on sugarcane juice quality under normal soil condition

Sr. No.	Treatment	Brix	Purity	CCS	Sucrose	Reducing sugar	CCS (t ha^{-1})
		-------------------- Per cent------------					
1	AC	22.10	91.71	14.92	20.05	0.19	9.53
2	RSW+BC	22.39	89.70	12.13	20.34	0.23	10.33
3	PBSW+BC	22.30	90.44	12.28	20.54	0.25	10.71
4	RSW+STC	22.73	91.82	13.09	21.65	0.24	10.61
5	PBSW+STC	22.43	95.11	12.88	21.54	0.27	10.67
6	RSW+PMC	22.50	94.40	12.64	20.57	0.25	13.12
7	PBSW+PMC	22.80	92.14	13.19	21.10	0.35	14.37
8	RSW+WSC	22.51	91.50	12.66	20.41	0.26	10.70
9	PBSW+WSC	22.74	91.07	12.83	20.45	0.27	10.89
10	RSW+PeBWC	22.81	90.54	12.39	20.54	0.26	10.51
11	PBSWC+PeBWC	21.65	94.79	12.01	19.92	0.26	10.19
12	RSW+CSC	22.58	90.80	12.92	21.00	0.26	12.48
13	PBSW+CSC	22.60	93.77	13.04	20.91	0.26	13.16
14	FYM (AST)	21.75	92.01	12.31	20.12	0.24	10.02
15	VC (AST)	21.85	91.79	11.78	20.23	0.24	9.70
16	RDF (AST)	22.14	91.73	13.08	21.06	0.27	9.85
	SE ±	0.45	0.81	0.76	0.45	0.01	0.33
	CD at 5 %	NS	2.33	NS	NS	0.02	0.96

Table 31. Effect of spent wash bio-compost application on sugarcane juice quality under sodic condition

Sr. No.	Treatment	Brix	Purity	CCS	Sucrose	Reducing sugar	CCS (t ha^{-1})
		---------------------- Per Cent-------------					
1	AC	22.85	90.34	12.78	20.38	0.20	6.53
2	RSW+BC	22.64	91.81	13.10	20.82	0.24	8.92
3	PBSW+BC	22.70	86.21	11.99	19.57	0.24	8.36
4	RSW+STC	23.38	90.31	13.44	20.63	0.26	8.64
5	PBSW+STC	22.81	89.69	12.60	20.19	0.26	8.34
6	RSW+PMC	23.07	91.51	13.34	20.59	0.28	11.08
7	PBSW+PMC	21.84	90.80	12.27	19.40	0.27	10.69
8	RSW+WSC	22.91	91.91	13.30	20.94	0.25	8.99
9	PBSW+WSC	21.53	93.81	12.55	19.65	0.25	8.50
10	RSW+PeBWC	21.81	89.74	12.58	19.71	0.27	8.51
11	PBSWC+PeBWC	22.07	87.77	12.03	18.73	0.25	8.17
12	RSW+CSC	22.10	90.13	12.67	20.10	0.26	9.80
13	PBSW+CSC	22.21	88.90	12.31	19.38	0.26	9.94
14	FYM (AST)	23.24	91.31	13.31	20.92	0.25	8.67
15	VC (AST)	22.30	91.26	12.66	19.71	0.24	8.34
16	RDF (AST)	22.27	88.96	12.34	19.61	0.22	7.43
	SE ±	1.87	0.87	0.19	0.32	0.01	0.14
	CD at 5 %	NS	2.51	0.53	0.92	0.03	0.41

4.8 Effect of spent wash bio-compost on nutrient uptake

The data in respect of total N, P and K uptake by *suru* sugarcane under normal and sodic soil condition are depicted in tables 32 and 33.

A. Normal soil

The results of NPK uptake indicate that, the N uptake (Fig. 6) ranged from 147.53 (control) to 259.00 kg ha^{-1} (PBSW + PMC), the P uptake (Fig. 7) ranged from 23.43 (Control) to 47.47 kg ha^{-1} (RSW + PMC) and K uptake (Fig. 8) ranged from 164.23 kg ha^{-1} (control) to 279.02 kg ha^{-1} (RSW + PMC). Thus, the application of spent wash bio-compost prepared from different crop residues significantly increased the N, P and K uptake over control, RDF, FYM and vermicompost. The results indicated that the press mud compost prepared from raw spent wash as well as post bio-methanated spent wash showed significantly highest NPK uptake by sugarcane followed by compost prepared from post bio-methanated spent wash + chickpea straw. The compost prepared from other crop residues showed comparable effect on uptake of NPK with FYM and vermicompost.

In general, the use of either raw spent wash or post bio-methanated compost prepared from different crop residues showed significantly higher NPK uptake over RDF and control.

B. Sodic soil

The results of NPK uptake are depicted in table 33 indicate that, the N, P and K uptake (Fig. 9 to 11) was significantly increased due to application of spent wash bio-compost over control, RDF, FYM and vermicompost. Among the spent wash bio-composts prepared the application of PBSW + PMC showed highest uptake of N, P and K (177.12, 27.81 and 206.58 kg ha^{-1}, respectively) followed by PBSW + CSC. In general, the use of post bio-methanated spent wash in different crop residues for composting showed significant increase in NPK uptake as compared to use of raw spent wash.

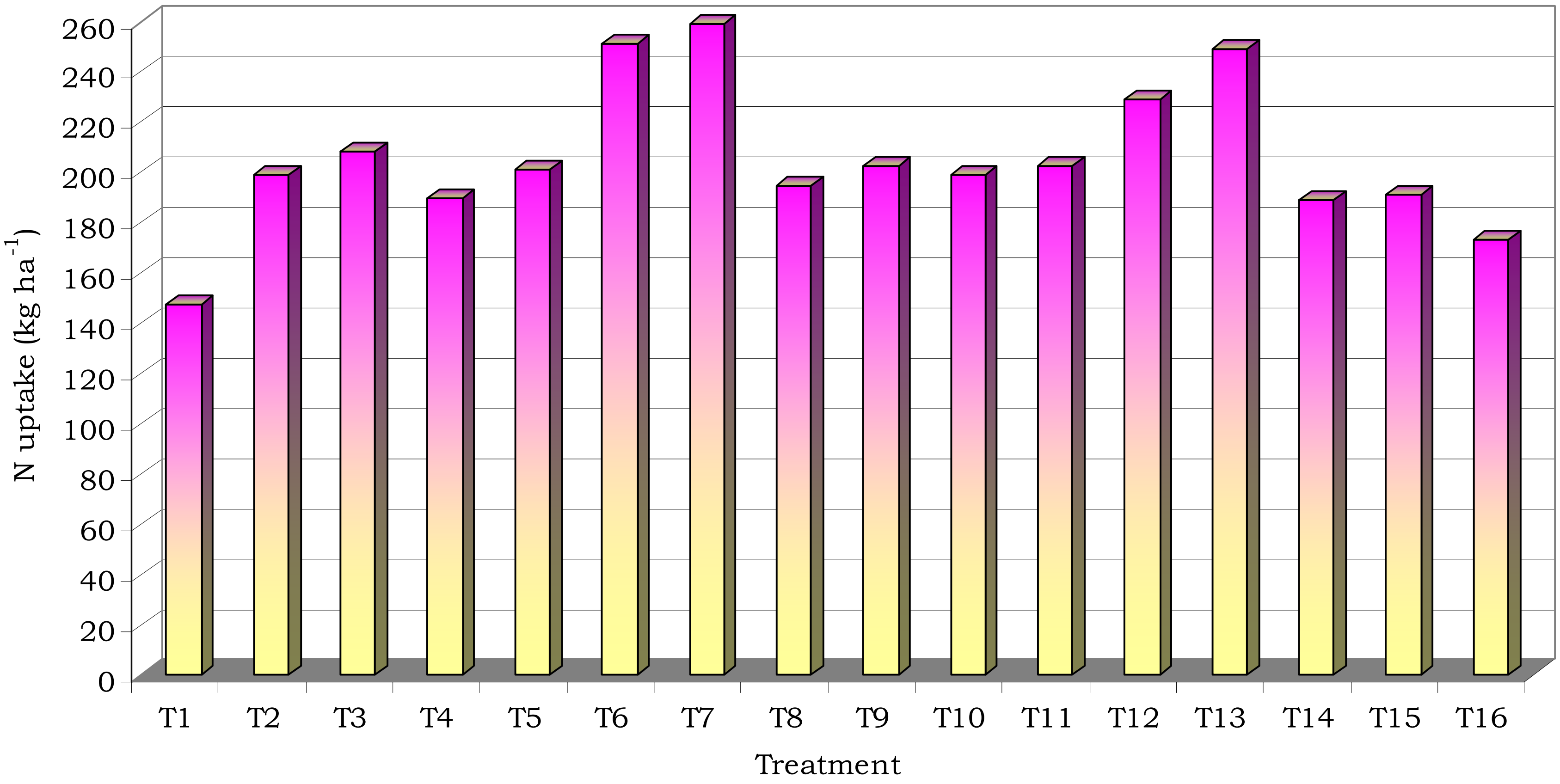

Fig. 6. Effect of spent wash bio-compost application of N uptake under normal soil

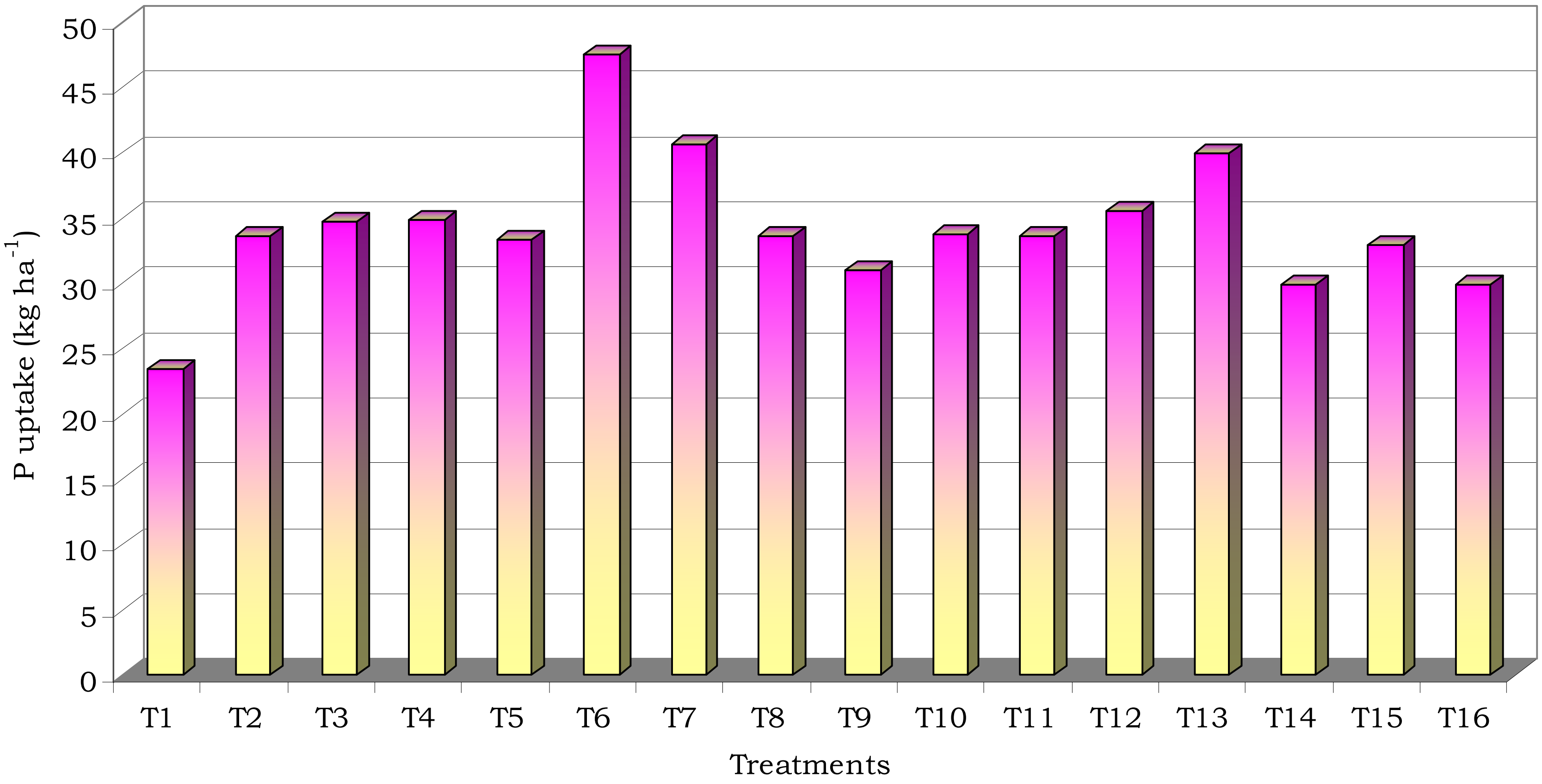

Fig. 7. Effect of spent wash bio-compost application of P uptake under normal soil

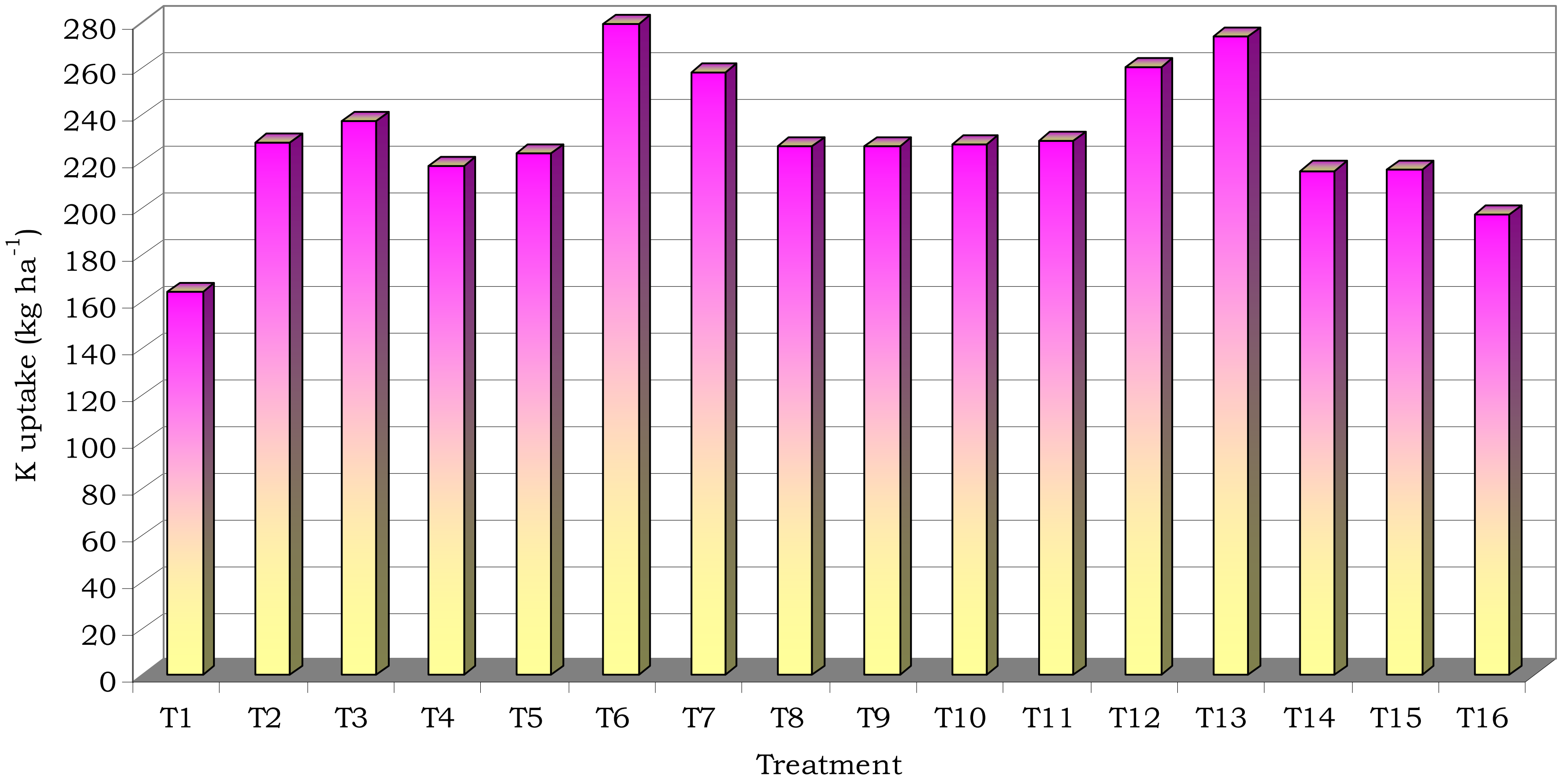

Fig. 8. Effect of spent wash bio-compost application of K uptake under normal soil

The application of spent wash compost increased the NPK uptake as compared to RDF as reported by Shinde *et al.* (1993) to sorghum fodder, Bhalerao *et al.* (2006) for seasonal sugarcane (plant and ratoon) and Patil *et al.* (2000) for maize.

The increase in NPK uptake by *suru* sugarcane could be due to increasing mineralizable nitrogen, solubility of phosphorous and enhancing K supplying capacity of soil due to improvement in physical, chemical and biological properties of soil which was resulted in improving bio-availability of nutrients and root growth characters.

Table 32. Effect of spent wash bio-compost application on total NPK uptake of sugarcane under normal soil condition

Sr. No.	Treatment	Total uptake		
		N	P	K
		-------------------(kg ha^{-1})-------------------		
1	AC	147.53	23.43	164.23
2	RSW+BC	198.80	33.63	228.03
3	PBSW+BC	208.27	34.70	237.15
4	RSW+STC	189.42	34.83	217.89
5	PBSW+STC	201.27	33.30	223.34
6	RSW+PMC	251.00	47.47	279.02
7	PBSW+PMC	259.00	40.57	258.45
8	RSW+WSC	194.67	33.63	226.86
9	PBSW+WSC	202.90	30.93	226.81
10	RSW+PeBWC	198.70	33.67	227.64
11	PBSWC+PeBWC	202.93	33.63	229.17
12	RSW+CSC	229.03	35.53	260.43
13	PBSW+CSC	248.87	39.87	273.76
14	FYM (AST)	188.97	29.87	216.26
15	VC (AST)	191.43	32.97	216.63
16	RDF (AST)	173.37	29.83	197.40
	SE ±	3.45	0.50	8.71
	CD at 5 %	9.96	1.43	25.15

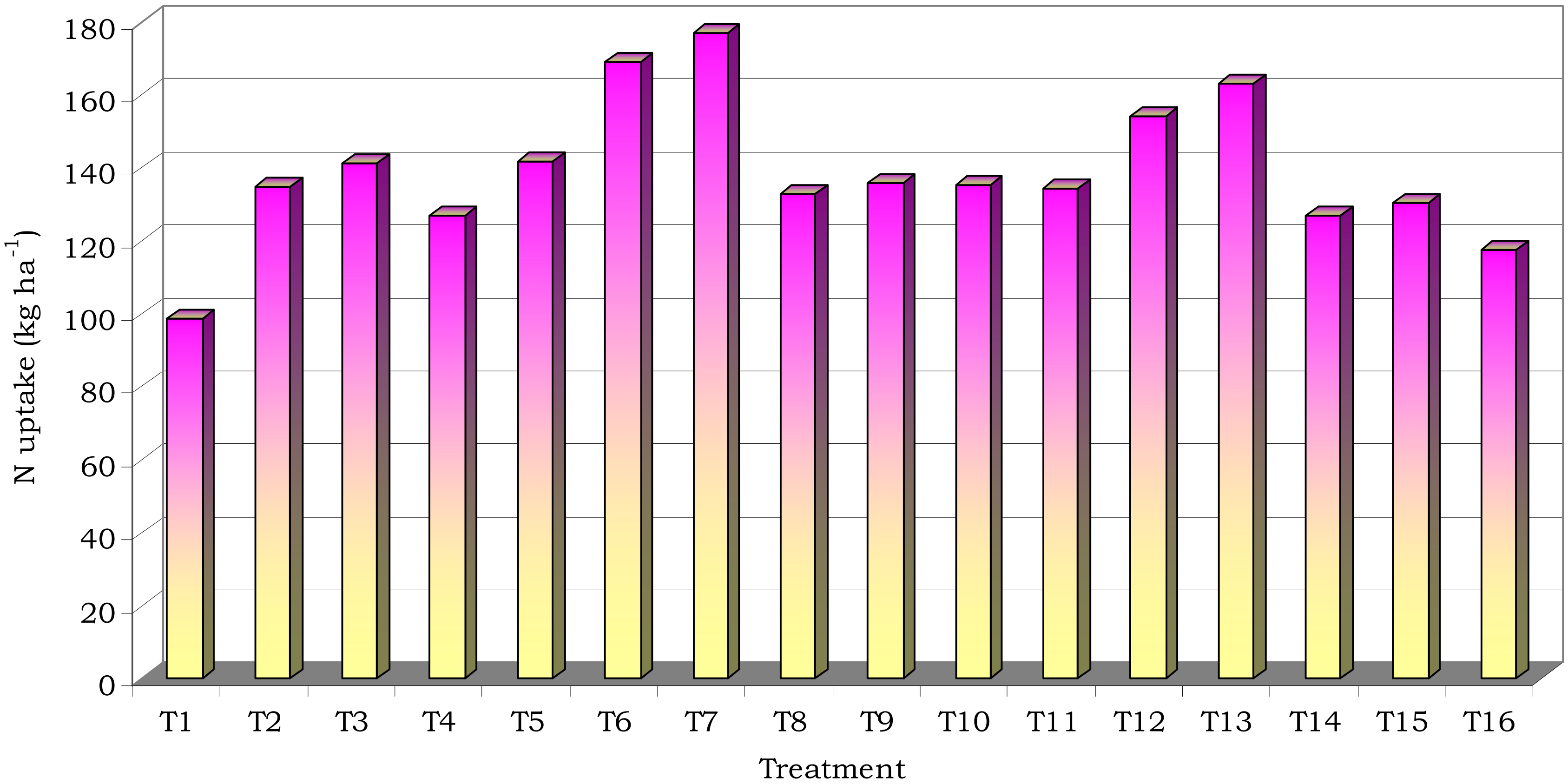

Fig. 9. Effect of spent wash bio-compost application of N uptake under sodic soil

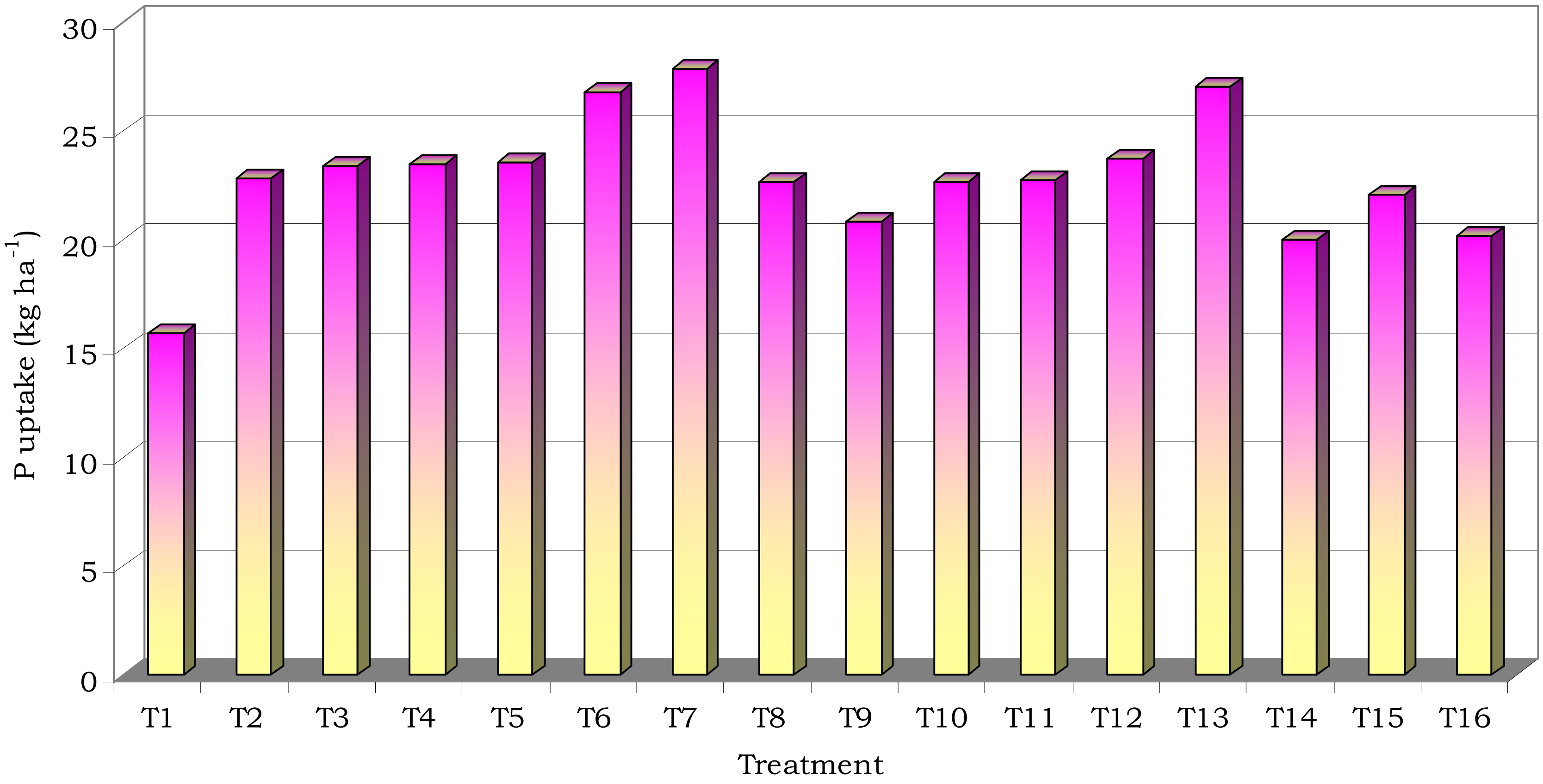

Fig. 10. Effect of spent wash bio-compost application of P uptake under sodic soil

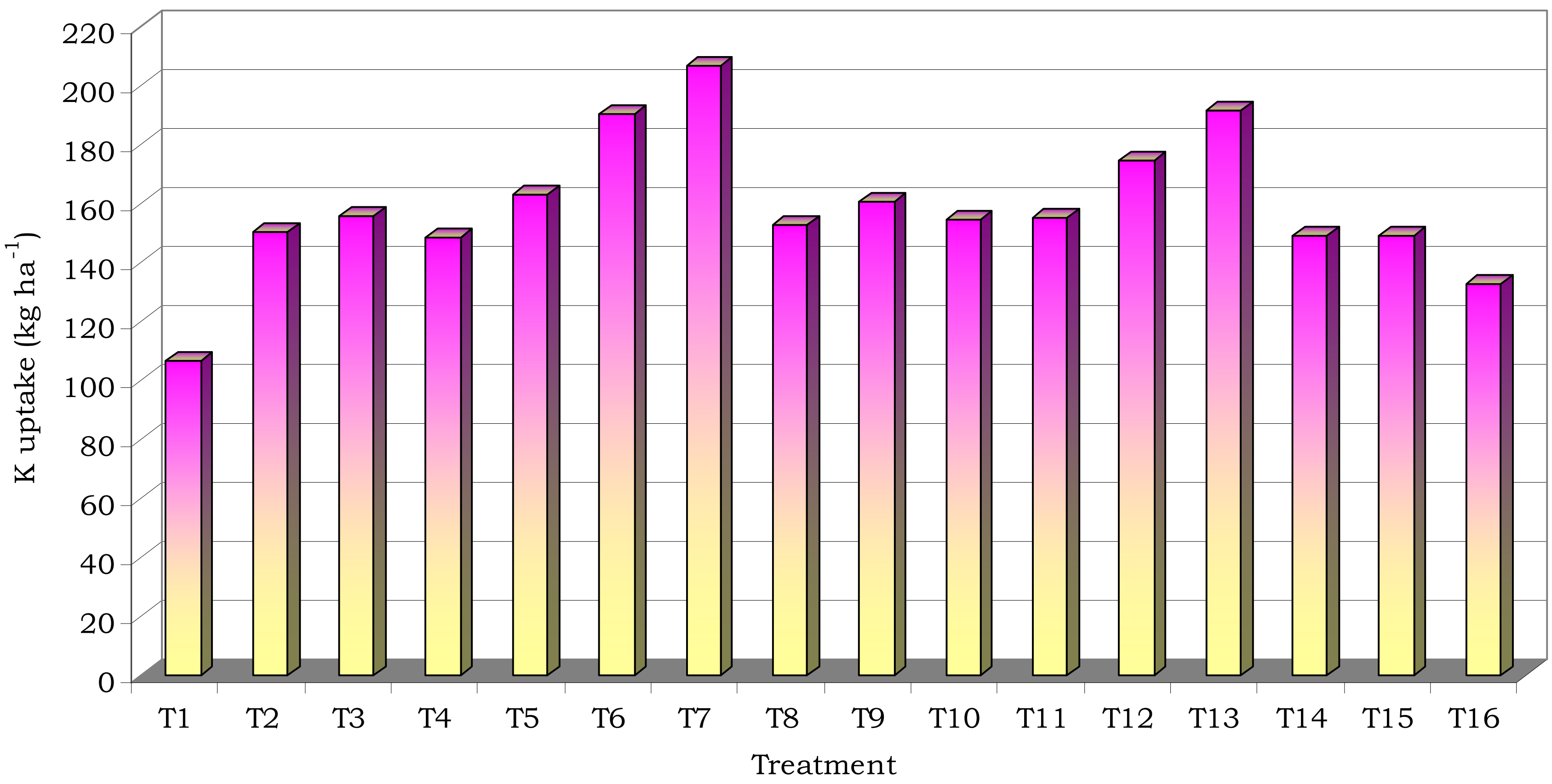

Fig. 11. Effect of spent wash bio-compost application of K uptake under sodic soil

Table 33. Effect of spent wash bio-compost application on total NPK uptake of sugarcane under sodic soil condition

Sr. No.	Treatment	Total uptake		
		N	P	K
		-------------------(kg ha^{-1})--------------------		
1	AC	98.79	15.67	106.85
2	RSW+BC	134.86	22.80	150.13
3	PBSW+BC	141.23	23.36	155.71
4	RSW+STC	127.04	23.50	148.23
5	PBSW+STC	141.93	23.54	162.85
6	RSW+PMC	168.81	26.73	190.05
7	PBSW+PMC	177.12	27.81	206.58
8	RSW+WSC	132.64	22.63	152.77
9	PBSW+WSC	135.64	20.79	160.68
10	RSW+PeBWC	135.38	22.64	154.73
11	PBSWC+PeBWC	134.16	22.73	155.28
12	RSW+CSC	154.16	23.72	174.58
13	PBSW+CSC	162.95	27.02	191.42
14	FYM (AST)	127.10	19.98	148.97
15	VC (AST)	130.30	22.04	148.75
16	RDF (AST)	117.53	20.14	132.59
	SE ±	3.27	0.50	3.54
	CD at 5 %	9.44	1.46	10.22

4.9 Effect of spent wash bio-compost on micro nutrient uptake

A. Normal soil

The data presented in table 34 in respect of micronutrient uptake by *suru* sugarcane indicated that, the application of spent wash compost and manures significantly increased the Fe, Mn, Cu and Zn uptake over control and RDF. Among the bio-composts, PBSW + PMC and PBSW + CSC showed higher uptake of Fe, Mn, Cu and Zn uptake over FYM and vermicompost.

B. Sodic soil

The data presented in Table 35 revealed that, the application of spent wash bio-composts significantly increased the uptake of Fe, Mn, Cu and Zn by sugarcane over control and RDF. The spent wash bio-compost prepared from press mud, chickpea straw and pearl millet straw showed significantly higher uptake of Fe, Mn, Cu and Zn over FYM and vermicompost. The use of bio-compost prepared from bio-methanated spent wash with chickpea straw compost (311.62 g ha^{-1}) and press mud cake compost (292.12 g ha^{-1}) showed significantly higher uptake of Zn over use of FYM and vermicompost.

The application of bio-compost and manures increased the micronutrient uptake by sugarcane could be due to increasing cationic concentration of micronutrients in soil solutions, chelating effect of micronutrients cations by humic substances produced during the process of decomposition and favouring improvement in physico-chemical properties of soil of treated plots with bio-compost as compared to control and RDF which might have enhanced the bio-availability of micro-nutrients under normal as well as sodic soil conditions. The increase in micronutrient uptake by application of spent wash was also reported by Shinde *et al.* (1993) in respect of Zn uptake in sorghum fodder, Chidankumar *et al.* (2010) reported that, highest uptake micro-nutrient in maize and wheat with application of diluted spent wash as compared to control.

Table 34. Effect of spent wash bio-compost application on micronutrient uptake by sugarcane in normal soil

Sr. No.	Treatment	Total micro-nutrients uptake			
		Normal soil			
		Fe	Mn	Cu	Zn
		----------------------(gha^{-1})-----------------			
1	AC	2411.76	83.31	81.28	408.81
2	RSW+BC	3952.19	113.82	113.82	542.39
3	PBSW+BC	4372.96	119.35	119.35	582.48
4	RSW+STC	3812.89	113.83	108.43	567.53
5	PBSW+STC	4231.20	113.28	110.64	555.94
6	RSW+PMC	4849.14	138.83	142.13	728.25
7	PBSW+PMC	5469.60	149.05	152.51	689.91
8	RSW+WSC	3952.09	112.96	112.96	564.94
9	PBSW+WSC	4296.80	113.24	110.54	566.08
10	RSW+PeBWC	4313.36	110.66	110.66	539.81
11	PBSWC+PeBWC	4672.33	113.44	113.44	568.83
12	RSW+CSC	5675.47	129.01	132.08	676.72
13	PBSW+CSC	6272.40	138.11	141.32	735.56
14	FYM (AST)	4148.48	106.23	108.82	518.31
15	VC (AST)	3869.28	107.52	107.52	523.69
16	RDF (AST)	3803.36	92.96	92.96	441.48
	SE ±	227.04	2.20	1.78	8.46
	CD at 5 %	655.73	6.34	5.14	24.42`

Table 35. Effect of spent wash bio-compost application on micro-nutrient uptake by sugarcane in sodic soil

Sr. No.	Treatment	Total micro-nutrient uptake			
		Sodic soil			
		Fe	Mn	Cu	Zn
		----------------------(gha^{-1})-----------------			
1	AC	850.14	35.86	34.58	172.13
2	RSW+BC	1283.55	48.48	48.43	230.96
3	PBSW+BC	1373.88	50.67	50.78	247.03
4	RSW+STC	1217.48	46.20	46.07	241.61
5	PBSW+STC	1449.18	48.58	47.08	237.71
6	RSW+PMC	1582.70	59.15	60.47	301.31
7	PBSW+PMC	1636.56	62.95	64.89	292.12
8	RSW+WSC	1264.23	48.17	48.07	240.49
9	PBSW+WSC	1372.78	48.10	47.03	240.81
10	RSW+PeBWC	1375.60	46.94	46.96	229.09
11	PBSWC+PeBWC	1560.80	48.53	48.26	242.70
12	RSW+CSC	1871.52	54.98	56.24	288.54
13	PBSW+CSC	1912.55	58.39	60.13	311.62
14	FYM (AST)	1328.00	45.19	46.30	220.59
15	VC (AST)	1196.65	45.54	45.69	222.19
16	RDF (AST)	1154.72	40.74	40.74	193.26
	SE ±	60.33	0.82	0.71	3.15
	CD at 5 %	174.25	2.38	2.04	9.08

4.10 Effect of spent wash bio compost application on physical properties of soil after harvest of sugarcane

The data pertaining to physical properties of normal and sodic soil is depicted in Tables 36 and 37.

4.10.1 Effect on texture of soil

A. Normal Soil

The experimental soil used for field experiment was clayey in texture because taxonomically the soil is classified as Typic haplustert. The clay content of experimental soil ranged from 55.31 to 56.12 per cent indicating clay texture. The textural properties of soil and content of sand, silt and clay did not influence significantly due to application of spent wash bio-compost and manures. The percentage of sand ranged from 18.38 to 18.99 per cent while with range of silt content was from 25.53 to 25.87 per cent being a permanent soil property.

B. Sodic Soil

The experimental soil was taxonomically classified as sodic haplustert having clay texture. The texture of sand, silt and clay was not altered due to application of spent wash bio-compost and manures during the course of experimentation. The treatment variation was found to be non significant. The per cent sand was ranged from 18.35 to 18.95 per cent, silt was ranged from 25.50 to 25.93 % and clay content was ranged from 55.34 to 56.00 %.

4.10.2 Effect on bulk density of soil

A. Normal soil

The bulk density of normal soil ranged from 1.31 Mg m^{-3} (PBSW + CSC) to 1.39 Mg m^{-3} (Control and RDF). The applications of bio-composts significantly decreased the bulk density of soil as compared with control and RDF. Use of post bio-methanated spent wash chickpea bio-compost showed lowest soil bulk density (1.31 Mg m^{-3}) followed by press mud compost (1.32 Mg m^{-3}).

B. Sodic soil

The bulk density of sodic soil under different treatments ranged from 1.33 to 1.39 Mg m^{-3}, although these values were significantly different. However, these values were slightly increased due to application of bio-compost over control and RDF under sodic soil condition indicating negligible effect of bio-compost application on bulk density of treated soils because of its first year of application. The improvement of bulk density due to application of spent wash slurry to maize was also reported by Patil (1994).

4.10.3 Effect on hydraulic conductivity of soil

A. Normal soil

The data presented in Table 36 indicated that, the hydraulic conductivity (HC) values of soil under different treatments ranged from 0.42 to 0.69 cm hr^{-1}. The use of bio-compost significantly increased the hydraulic conductivity over control and RDF. The application of PBSW + PMC compost (0.69 cm hr^{-1}) and PBSW + chickpea compost (0.58 cm hr^{-1}) showed significant improvement in HC over the use of FYM and vermicompost.

B. Sodic soil

The hydraulic conductivity of sodic soil under different treatment ranged from 0.14 (control) to 0.26 cm hr^{-1} (PBSW + PMC). The application of spent wash composts showed significant improvement in HC over control, RDF, FYM and vermicompost. The effect of composts prepared from PBSW + PMC, PBSW + STC and PBSW + Chickpea straw showed comparatively higher HC over other bio-composts. The improvement in HC due to application of bio-compost specifically PMC, CSC and STC could be due to

Table 36. Effect of spent wash bio-compost application on physical properties of normal soil after harvest of sugarcane

Sr. No.	Treatment	Normal soil						
		Sand	Silt	Clay	Bulk density (Mg m^{-3})	Hydraulic conductivity (cm hr^{-1})	Dispersion Index	MWD (mm)
		------------- Per cent--------						
1.	AC	18.84	25.69	56.12	1.39	0.45	18.30	0.54
2.	RSW+BC	18.49	25.55	55.97	1.36	0.55	16.03	0.57
3.	PBSW+BC	18.77	25.65	55.58	1.38	0.53	14.80	0.58
4.	RSW+STC	18.78	25.64	55.58	1.35	0.56	16.01	0.56
5.	PBSW+STC	18.43	25.87	55.71	1.36	0.60	14.14	0.59
6.	RSW+PMC	18.75	25.67	55.58	1.32	0.55	16.10	0.58
7.	PBSW+PMC	18.72	25.76	55.53	1.34	0.69	14.18	0.58
8.	RSW+WSC	18.67	25.56	55.77	1.34	0.50	16.32	0.56
9.	PBSW+WSC	18.80	25.62	55.58	1.36	0.50	15.16	0.57
10.	RSW+PeBWC	18.75	25.84	55.41	1.33	0.53	16.22	0.57
11.	PBSWC+PeBWC	18.38	25.79	55.83	1.36	0.54	14.24	0.57
12.	RSW+CSC	18.40	25.60	56.00	1.32	0.55	16.37	0.55
13.	PBSW+CSC	18.42	25.57	55.92	1.31	0.58	14.00	0.57
14.	FYM (AST)	18.80	25.52	55.68	1.35	0.42	17.65	0.57
15.	VC (AST)	18.99	25.70	55.31	1.34	0.45	16.59	0.53
16.	RDF (AST)	18.38	25.66	55.91	1.39	0.46	18.00	0.53
	SE ±	0.201	0.129	0.30	0.007	0.07	0.83	0.006
	CD at 5 %	NS	NS	NS	0.019	0.020	1.11	0.016
	Initial	18.90	25.45	56.06	1.40	0.46	18.35	0.55

formation of stable clay humus complex as well as formation of good soil structure might have resulted proper void space to drain excess gravitational water. The improvement of HC of soil due to application of spent wash / spent wash compost was also reported by Pathak *et al.* (1999), Hati *et al.* (2003) and Khatal (2008).

4.10.4 Effect on dispersion index

A. Normal soil

The dispersion index of soil was ranged from 14.00 to 18.30. The significant decrease in dispersion index was observed due to application of spent wash bio-composts over control and RDF. The lowest dispersion index was observed by use of PBSW + Chickpea compost (14.00) and press mud compost (14.18).

B. Sodic soil

The dispersion index of soil was ranged from 28.35 (PBSW+ PeBWC) to 31.40 (RDF). The slight decrease in dispersion index was observed due to application of spent wash bio-composts over control and RDF. The comparatively lower values of dispersion index was observed by application of bio-compost prepared from post bio-methanated spent wash + Pearlmillet straw (28.35) and press mud compost (29.16) as compared to raw spent wash compost treatments. The higher dispersion index in control and RDF treatment could be due to more dispersion of clays and less stability of soil aggregates under sodic soil condition.

4.10.5 Effect on mean weight diameter (MWD)

A. Normal soil

The data presented in Table 36 indicate that MWD ranged from 0.53 (RDF) to 0.59 mm (PBSW +STC**).** In general, the use of spent wash bio-compost showed significant improvement in

MWD over control and RDF. Among the different bio-compost the PBSW+ STC showed highest MWD (0.59 mm) followed by PBSW+ PMC (0.58 mm). Improvement in MWD could be due to formation of stable clay humus complexes resulted in good soil structural aggregation.

B. Sodic soil

The data presented in Table 37 indicate that mean weight diameter of water stable aggregate of sodic soil improved significantly due to addition of spent wash bio-composts over control and RDF. The values ranged from 0.44 (RSW + PeBWC) to 0.53 mm (PBSW + PMC).

4.11 Effect of spent wash bio-compost application on chemical properties of soil after harvest of sugarcane

4.11.1 Effect on soil pH

The data in respect of effect of spent wash bio-compost on chemical properties of normal soil and sodic soil are presented in Tables 38 and 39.

A. Normal soil

The data revealed that, soil pH ranged from 8.10 (PBSW + PMC) to 8.30 (Control). The application of RSW+ PMC compost showed comparatively lower values of soil pH (8.10). The soil pH was higher where post bio-methanated spent wash was used as compared to application of raw spent wash. It could be due to the low pH of raw spent wash.

The decrease in soil pH might be attributed to the acidic nature of spent wash and release of organic acids during the decomposition.

Table 37. Effect of spent wash bio-compost application on physical properties of sodic soil after harvest of sugarcane

Sr. No.	Treatment	Sodic soil						
		Sand	Silt	Clay	Bulk density ($Mg\ m^{-3}$)	Hydraulic conductivity ($cm\ hr^{-1}$)	Dispersion Index	MWD (mm)
		-------------Per cent----						
1.	AC	18.67	25.56	55.77	1.33	0.14	31.33	0.43
2.	RSW+BC	18.80	25.62	55.58	1.35	0.21	30.18	0.46
3.	PBSW+BC	18.66	25.93	55.41	1.37	0.24	29.35	0.49
4.	RSW+STC	18.35	25.80	55.85	1.34	0.24	30.56	0.46
5.	PBSW+STC	18.40	25.60	56.00	1.36	0.26	29.16	0.48
6.	RSW+PMC	18.52	25.57	55.92	1.36	0.23	30.42	0.51
7.	PBSW+PMC	18.85	25.50	55.65	1.39	0.26	29.65	0.53
8.	RSW+WSC	18.95	25.71	55.34	1.36	0.22	30.32	0.47
9.	PBSW+WSC	18.38	25.66	55.96	1.35	0.24	29.42	0.48
10.	RSW+PeBWC	18.84	25.69	55.47	1.35	0.24	30.04	0.44
11.	PBSWC+PeBWC	18.49	25.55	55.97	1.36	0.23	28.35	0.48
12.	RSW+CSC	18.76	25.65	55.58	1.35	0.24	29.24	0.49
13.	PBSW+CSC	18.78	25.64	55.58	1.39	0.25	30.39	0.49
14.	FYM (AST)	18.43	25.87	55.71	1.34	0.15	30.98	0.51
15.	VC (AST)	18.70	25.67	55.58	1.36	0.16	30.39	0.52
16.	RDF (AST)	18.72	25.76	55.53	1.33	0.16	31.40	0.51
	SE ±	0.13	0.20	0.13	0.009	0.009	0.54	0.006
	CD at 5 %	NS	NS	NS	0.025	0.025	1.57	0.0017
	Initial	18.63	25.60	55.77	1.34	0.14	25.38	0.55

Table 38. Effect of spent wash bio-compost application on chemical properties of soil after harvest of *suru* sugarcane in normal soil

Sr. No.	Treatment	pH (1:2.5)	EC (dSm^{-1})	O.C. (per cent)	Avail. N	Avail. P	Avail. K
					-------------($kg\ ha^{-1}$)---------		
1.	AC	8.30	0.35	0.49	164.33	9.63	465
2.	RSW+BC	8.20	0.56	0.55	185.00	10.35	567
3.	PBSW+BC	8.24	0.50	0.56	203.80	11.93	572
4.	RSW+STC	8.22	0.56	0.55	189.00	10.41	580
5.	PBSW+STC	8.23	0.50	0.57	222.33	10.92	589
6.	RSW+PMC	8.10	0.47	0.65	194.00	14.15	600
7.	PBSW+PMC	8.13	0.42	0.69	222.03	13.81	620
8.	RSW+WSC	8.22	0.55	0.55	191.67	12.37	563
9.	PBSW+WSC	8.24	0.50	0.56	205.00	12.44	571
10.	RSW+PeBWC	8.21	0.55	0.56	191.67	12.35	763
11.	PBSWC+PeBWC	8.23	0.53	0.57	205.23	12.76	671
12.	RSW+CSC	8.11	0.46	0.60	198.33	14.77	573
13.	PBSW+CSC	8.13	0.44	0.67	224.33	13.02	493
14.	FYM (AST)	8.25	0.39	0.58	185.00	11.37	560
15.	VC (AST)	8.26	0.40	0.60	177.00	11.47	563
16.	RDF (AST)	8.27	0.42	0.51	174.00	10.10	541
	SE ±	0.01	0.01	0.05	2.37	0.07	5.90
	CD at 5 %	0.04	0.03	0.01	6.81	0.20	17.00
	Initial	8.25	0.35	0.47	165.20	9.75	470

B. Sodic soil

The application of spent wash bio-composts resulted in significant decrease in pH over control and RDF. The application of PBSW + chickpea straw compost showed lowest soil pH as compared to FYM and vermicompost. The application of RSW + STC, RSW + PMC, RSW + WCS showed significantly lowest soil pH (8.70) as compared with RDF, FYM and vermicompost. It could be due to acidic nature of raw spent wash.

Table 39. Effect of spent wash bio-compost application on chemical properties of soil after harvest of *suru* sugarcane in sodic soil

Sr. No.	Treatment	pH (1:2.5)	EC (dSm^{-1})	O.C. (per cent)	Avail. N	Avail. P	Avail. K
					------------(kg ha^{-1})---------		
1.	AC	8.81	1.13	0.38	151	6.89	397
2.	RSW+BC	8.71	1.19	0.42	160	7.95	419
3.	PBSW+BC	8.75	1.15	0.44	166	8.30	428
4.	RSW+STC	8.70	1.19	0.40	155	7.95	418
5.	PBSW+STC	8.76	1.17	0.42	164	8.37	424
6.	RSW+PMC	8.70	1.19	0.55	158	8.55	415
7.	PBSW+PMC	8.75	1.14	0.65	167	8.85	458
8.	RSW+WSC	8.70	1.19	0.40	158	8.17	424
9.	PBSW+WSC	8.75	1.17	0.45	164	8.60	450
10.	RSW+PeBWC	8.72	1.20	0.41	162	8.65	429
11.	PBSWC+PeBWC	8.74	1.14	0.43	166	8.90	441
12.	RSW+CSC	8.70	1.19	0.60	156	8.35	430
13.	PBSW+CSC	8.74	1.15	0.69	167	8.58	438
14.	FYM	8.80	1.09	0.42	156	8.21	423
15.	VC	8.80	1.11	0.50	154	8.15	427
16.	RDF (AST)	8.80	1.10	0.42	151	8.10	435
	SE ±	0.01	0.01	0.01	1.93	0.16	3.36
	CD at 5 %	0.03	0.03	0.03	5.55	0.46	9.69
	Initial	**8.82**	**1.12**	**0.37**	**153**	**7.60**	**390**

Saliha (2003) reported that increase in level of the spent wash application resulted a notable decrease in the pH of soils and

such effect was more pronounced in the presence of organic amendments. Decrease in soil pH might be attributed to the acidic nature of spent wash and release of organic acids during the decomposition. Similar observations were also recorded by Pawar *et al.* (1992), Chaudhary (1998), Kayalvizhi *et al.* (2001) and Khatal (2008).

4.11.2 Effect on soil electrical conductivity (EC)

A. Normal soil

The EC values in normal soil are depicted in Table 38. The electrical conductivity was ranged from 0.35 dSm^{-1} (Control) to 0.56 dSm^{-1} (RSW+ STC). Lowest EC was found in control, FYM, vermicompost and RDF treated plots where spent wash was not used. Comparatively use of post bio-methanated spent wash, bio-compost showed lower EC values than raw spent wash bio-compost (Fig 12). It could be due to high salt load in raw spent wash as compared to the post bio-methanated spent wash.

B. Sodic soil

The EC was ranged from 1.09 dSm^{-1} (FYM) to the 1.20 dSm^{-1} (RSW+PeBWC) (Table 39). Raw spent wash bio-compost treated plots were found high in electrical conductivity as compared to PBSW, control, FYM, vermicompost and RDF treated plots(Fig 13). The application of spent wash resulted in

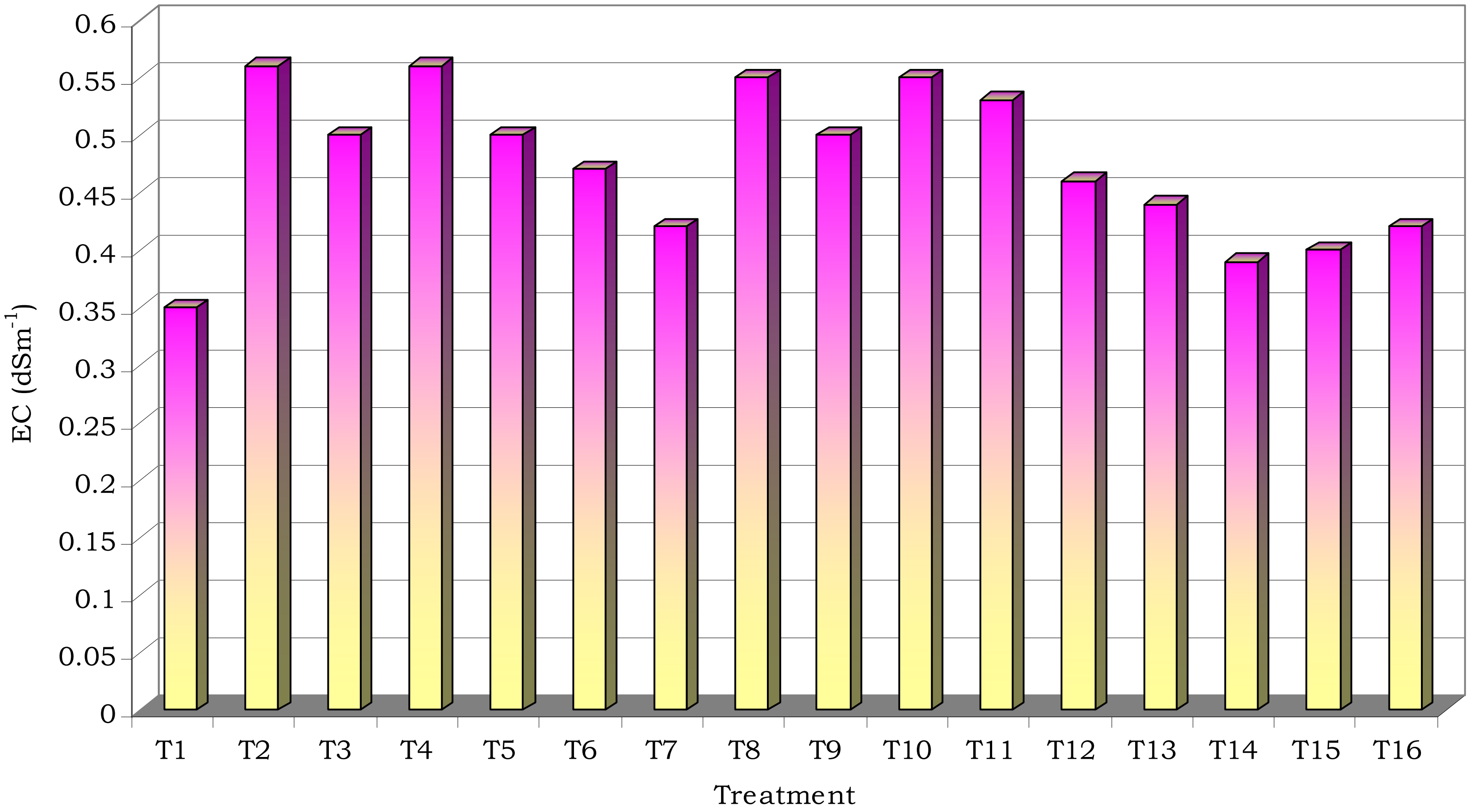

Fig. 12. Effect of spent wash bio-compost application on EC of normal soil

increase of EC values was also reported by Joshi *et al.* (1994) Singh and Bahadur (1998) Chaudhary (1998) and Pathak et al. (1999).

4.11.3 Effect on soil organic carbon

A. Normal soil

The organic carbon content of soil under different treatments ranged from 0.49 per cent (Control) to 0.69 per cent (PBSW + PMC). The application of spent wash composts significantly increased the organic carbon status as compared to the control, and RDF. Among the treatments PBSW + PMC showed significantly higher organic carbon content (0.69 per cent) followed by RSW + PMC (0.65 per cent). In general, it was observed that the spent wash bio-compost prepared from different crop residues significantly increased organic carbon content over the control and RDF.

It could be due to organic matter content in the spent wash as well as presence of humic substances in the bio-compost.

B. Sodic soil

The organic carbon content in different treatments ranged from 0.38 percent (control) to 0.69 per cent (PBSW+ CSC). The significantly higher organic carbon content was recorded in the treatment of PBSW + CSC (0.69 per cent) followed by PBMSW + PMC (0.65 per cent). The application of spent wash /spent wash compost increased the soil organic

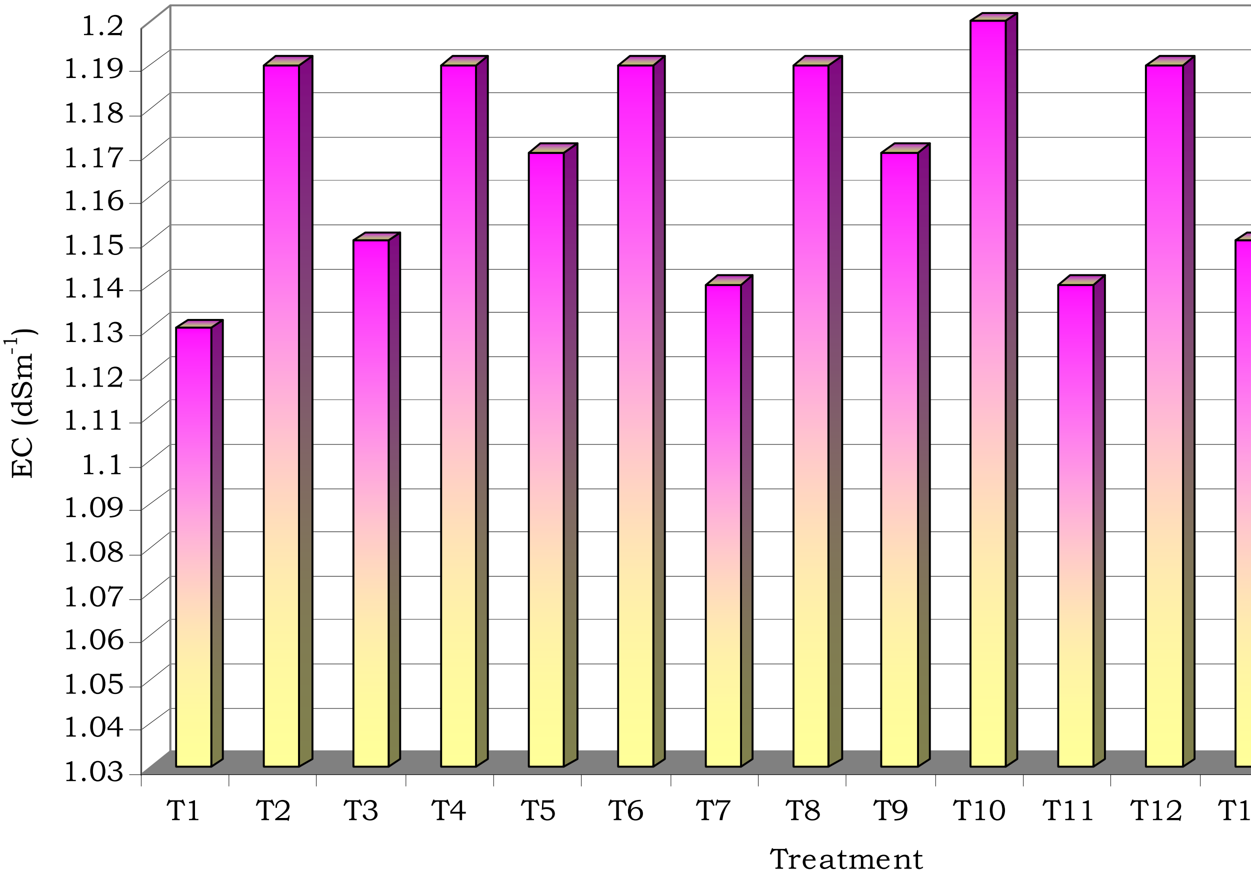

Fig. 13. Effect of spent wash bio-compost application on EC of s

carbon was also reported by Singh (1992), Singh *et al.* (1995), Chaudhary (1998) and Pathak *et al.* (1999).

4.11.4 Effect on soil available nitrogen content.

A. Normal soil

The available nitrogen in normal soil ranged from 164.33 (Control) to 224.33 kg ha^{-1} (PBSW+ CSC). The significantly higher available nitrogen was found in the treatment of post bio-methanated spent wash + chickpea straw compost (224.33 kg ha^{-1}) followed by (PBSW + CSC) (222.33 kg ha^{-1}). The available nitrogen was increased in all the treatments where the spent wash bio-compost was applied as compared to the control, FYM, vermicompost and RDF.It could be due to increase in organic carbon status and formation of different soil humic substances associated with higher mineralization rate.

B. Sodic Soil

The available nitrogen in sodic soil was ranged from 151 (control) to 167 kg ha^{-1} (PBSW+ PMC). The application of spent wash bio-compost showed significant improvement in available status of nitrogen as compared to RDF.

4.11.5 Effect on soil available phosphorous

A. Normal soil

The available phosphorus was significantly higher where both the spent wash bio-composts were used as compared to the control, and RDF. The available P status was ranged from 9.63 (Control) to 14.77 kg ha^{-1} (RSW +SCS). The available P content was significantly increased by application of RSW + chickpea starw bio-compost.

B. Sodic soil

The available P ranged from 6.89 (control) to 8.90 kg ha^{-1} (PBSW+ PeBSWC). Application of bio-compost resulted in significant increase in available P status of soil over control.

The results indicate that the application of bio-compost might have increased the phosphatase activities in the soil. The similar views were also reported by Selvamurugan *et al.* (2011) for soils of Coimbatore. Similar observations were also reported by Devarajan and Oblisami (1995), Zalawadia and Raman (1994) and Chaudhary (1998).

4.11.6 Effect on soil available potassium

A. Normal soil

The application of spent wash composts significantly increased the soil available K status over control and RDF. The highest available K content (763 kg ha^{-1}) was reported in RSW + pearl millet straw compost treated plot over FYM.

B. Sodic soil

The available K status was ranged from 397 (Control) to 458 kg ha^{-1} (PBSW+PMC). The application of bio-compost significantly improved available K status of soil over control. The increase in available status could be due to presence of higher K content in spent wash.

The application of spent wash bio-compost resulted in improving the available NPK status of the soil was noticed over control and RDF. These results are in conformity with the results of Chaudhary (1998), Kayalvizhi *et al.* (2001) and Bhalerao *et al.* (2006).

4.11.7 Effect on available soil micronutrients

A. Normal soil

The data in respect of micronutrients cation are depicted in Tables 40 and 41 in normal and sodic soil respectively. Data revealed that, the application of spent wash composts significantly increased the DTPA extractable Fe, Mn, Zn, and Cu over control and RDF. The DTPA Fe content ranged from 5.20 (Control) to 6.49 mg kg^{-1} (PBSW + PMC).Whereas the DTPA Zn ranged from 0.61 (Control) to 0.99 mg kg^{-1} (PBSW + PeBWC).

B. Sodic soil

The soil micro-nutrients viz., available Fe, Mn, Zn and Cu content were significantly increased over control. The PBSW compost prepared from pearl millet, chickpea and PMC showed significantly

higher values of available Fe, Mn, Zn and Cu content over RDF and use of FYM. The use of spent wash bio-compost increased the bio- availability of micronutrients could be due to increase in organic carbon status helped for release of micronutrients from soil as well as from bio-compost, effect of humic substances through chelating actions and reducing the fixation capacity of micro-nutrient cations in soil. The similar views are also reported by Devarajan and Oblisami (1995), Kayalvizhi *et al.* (2001), Khatal (2008) and Durgude *et al.* (2010).

Table 40. Effect of spent wash bio-compost application on DTPA micronutrients in soil after harvest of *suru* sugarcane in normal soil

Sr. No.	Treatment	Fe	Mn	Zn	Cu
		------------------ (mg kg^{-1})----------------			
1.	AC	5.20	9.66	0.61	3.86
2.	RSW+BC	6.39	12.38	0.79	4.02
3.	PBSW+BC	6.48	13.15	0.63	4.05
4.	RSW+STC	6.42	13.73	0.81	4.01
5.	PBSW+STC	6.47	13.90	0.65	4.10
6.	RSW+PMC	6.41	13.64	0.90	4.01
7.	PBSW+PMC	6.49	14.79	0.70	4.05
8.	RSW+WSC	6.40	14.28	0.70	4.10
9.	PBSW+WSC	6.43	15.25	0.60	4.9
10.	RSW+PeBWC	6.33	13.97	0.75	4.13
11.	PBSWC+PeBWC	6.43	14.45	0.99	4.16
12.	RSW+CSC	6.34	14.09	0.90	4.12
13.	PBSW+CSC	6.46	14.45	0.83	4.15
14.	FYM	6.34	13.54	0.69	3.96
15.	VC	6.31	13.46	0.72	3.98
16.	RDF (AST)	6.17	10.15	0.66	4.30
	SE ±	0.01	1.19	0.01	0.09
	CD at 5 %	0.03	3.44	0.02	0.26
	Initial	5.25	10.15	0.63	3.85

Table 41. Effect of spent wash bio-compost application on DTPA micronutrients in soil after harvest of *suru* sugarcane in sodic soil

Sr. No.	Treatment	Fe	Mn	Zn	Cu
		------------(mg kg^{-1})--------------			
1.	AC	4.00	9.69	0.35	0.84
2.	RSW+BC	4.18	10.82	0.38	0.93
3.	PBSW+BC	4.22	12.43	0.41	0.96
4.	RSW+STC	4.21	9.10	0.44	0.97
5.	PBSW+STC	4.22	10.10	0.47	1.04
6.	RSW+PMC	4.30	12.25	0.48	1.03
7.	PBSW+PMC	4.35	13.52	0.51	1.12
8.	RSW+WSC	4.22	11.24	0.44	0.98
9.	PBSW+WSC	4.24	10.92	0.43	1.00
10.	RSW+PeBWC	4.16	9.45	0.49	0.93
11.	PBSWC+PeBWC	4.18	9.87	0.50	0.94
12.	RSW+CSC	4.30	12.15	0.48	1.04
13.	PBSW+CSC	4.33	13.77	0.50	0.98
14.	FYM	4.24	9.68	0.43	0.92
15.	VC	4.22	9.78	0.44	0.84
16.	RDF (AST)	4.20	9.85	0.43	0.85
	SE ±	0.01	0.64	0.22	0.03
	CD at 5 %	0.04	1.84	0.06	0.09
	Initial	4.10	9.72	0.39	0.88

4.11.8 Effect on soil exchangeable cations

The results in respect of exchangeable cations of normal and sodic soils are depicted in Tables 42 and 43 , respectively.

A. Normal soil

The data indicated that exchangeable Ca^{2+} did not significantly influence by spent wash bio-compost application whereas exchangeable Mg^{2+}, Na^{+} and K^{+} were increased significantly over control, RDF, FYM and vermicompost. The exchangeable Na+ ranged from 4.56 (Control) to 7.22 Cmol(P^{+}) kg^{-1} (PBSW + CSC). The exchangeable potassium was ranged from 0.80 (Control) to 1.96 Cmol(P^{+}) kg^{-1}(PBSW + BC). The significant built up of exchangeable K^{+} was observed, by use of spent wash bio-composts over FYM and vermicompost

B. Sodic soil

The exchangeable Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} content of soil was significantly increased due to application of spent wash bio-composts over control and RDF(Table 43). Thus, the results indicate the ameliorating effects of bio-compost for enhancing the exch. calcium on clay complex under sodic soil condition. The exchangeable Ca^{2+}, Mg^{2+} , Na^{+} and K+ content in control treatment was 14.90, 13.20, 13.45, and 0.90 Cmol (P^{+})kg^{-1}, respectively. The significant higher exchangable Ca^{2+} (PBSW+PMC), exchangeable Mg^{2+} (RSW+ PMC), Na^{+} (PBSW +CSC) and K^{+} (RSW + PMC) was noticed under sodic soil condition. Thus, the results showed that, the application of spent wash bio-compost significantly increased the exch.cations under normal and sodic condition. The results are in accordance with the findings of Devarajan and Oblisami (1995), Pawar *et al.* (1992) and Anandakrishnan *et al.* (2008).

Table 42. Effect of spent wash bio-compost application on chemical properties of normal soil

Sr. No.	Treatment	Normal soil (Exchangeable Cations)						
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CEC	ESP	EMP
		----------(Cmol(P+) kg^{-1})------------						
1.	AC	36.57	19.25	4.56	0.80	61.34	7.42	31.38
2.	RSW+BC	41.78	24.32	6.75	1.80	74.85	9.26	32.49
3.	PBSW+BC	43.13	22.45	7.85	1.96	75.42	9.40	29.77
4.	RSW+STC	41.37	22.90	6.80	1.55	73.68	9.08	31.08
5.	PBSW+STC	42.92	22.10	7.10	1.60	73.95	9.68	29.89
6.	RSW+PMC	44.10	23.50	6.42	1.50	75.60	8.50	31.08
7.	PBSW+PMC	44.39	22.80	6.62	1.85	75.77	8.58	30.09
8.	RSW+WSC	42.37	21.30	6.45	1.86	72.00	8.89	29.58
9.	PBSW+WSC	45.04	20.15	7.10	1.88	74.22	9.58	27.15
10.	RSW+PeBWC	41.37	23.55	6.32	1.79	73.21	8.58	32.17
11.	PBSWC+PeBWC	43.47	22.12	7.10	1.86	74.64	9.46	29.64
12.	RSW+CSC	44.83	22.62	6.85	1.79	76.20	9.03	29.69
13.	PBSW+CSC	44.04	22.75	7.22	1.82	75.88	9.67	29.98
14.	FYM (AST)	38.38	19.87	5.52	0.95	64.82	8.44	30.65
15.	VC (AST)	38.45	19.88	4.32	0.92	63.62	6.86	31.25
16.	RDF (AST)	37.87	19.93	4.13	0.90	62.50	6.60	31.89
	SE ±	1.84	0.54	0.169	0.015	0.592	0.195	0.82
	CD at 5 %	NS	1.54	0.488	0.042	1.71	0.563	2.37
	Initial	37.50	20.30	4.10	0.80	61.55	7.55	32.98

Table 43. Effect of spent wash bio-compost application on chemical properties of sodic soil

Sr. No.	Treatment	Sodic soil (Exchangeable Cations)						
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CEC	ESP	EMP
		------------ (Cmol(P+) kg^{-1})--------						
1.	AC	14.90	13.20	13.45	0.19	44.80	20.12	25.65
2.	RSW+BC	20.35	13.80	14.52	0.35	49.02	29.62	28.16
3.	PBSW+BC	20.45	14.30	15.3	0.25	50.30	30.42	28.44
4.	RSW+STC	19.10	14.65	15.12	0.34	49.21	30.73	29.77
5.	PBSW+STC	20.35	15.20	15.42	0.27	51.23	30.09	29.61
6.	RSW+PMC	19.93	15.22	14.32	0.34	49.80	28.75	30.55
7.	PBSW+PMC	23.45	14.90	15.32	0.30	53.98	28.39	27.61
8.	RSW+WSC	19.50	13.45	14.2	0.32	47.46	29.91	28.32
9.	PBSW+WSC	19.55	14.20	14.6	0.30	48.65	30.01	29.21
10.	RSW+PeBWC	18.77	13.40	14.2	0.32	46.69	30.41	28.70
11.	PBSWC+PeBWC	19.80	14.35	14.9	0.26	49.31	30.22	29.11
12.	RSW+CSC	19.50	13.60	14.65	0.34	48.09	30.46	28.29
13.	PBSW+CSC	20.35	14.30	15.65	0.27	50.56	30.95	28.28
14.	FYM (AST)	18.20	14.69	13.2	0.30	46.39	21.45	31.70
15.	VC (AST)	18.33	14.30	11.32	0.32	44.28	22.35	32.29
16.	RDF (AST)	18.10	13.20	12	0.30	43.60	21.35	30.28
	SE ±	0.456	0.349	0.377	0.012	0.669	0.32	0.655
	CD at 5 %	1.317	1.008	1.088	0.035	1.931	0.93	1.891
	Initial	15.32	13.22	13.50	0.20	45.0	20.22	26.45

4.11.9 Effect on cation exchange capacity, exchangeable sodium percentage, and exchangeable magnesium percentage

A. Normal soil

The data presented in normal soil is depicted in Table 42. The CEC values of soil ranged from 61.34(control) to 76.20 Cmol (P^{+}) kg^{-1} (RSW + CSC).The CEC values significantly increased due to application of spent wash composts over control, RDF, FYM and vermicompost. The ESP values were significantly increased due to application of spent wash bio-composts over RDF, FYM and vermicompost.However, the treatment effects did not enhanced the sodic condition as these values were less than 15.The EMP values ranged from 29.58 (RSW+ WSC) to 32.49 (RSW +BC). Use of PBSW showed comparatively lower values than RSW.

B. Sodic Soil

The result in respect of sodic soil is given in Table 43. The use of spent wash bio-composts significantly increased the CEC values over control, RDF and Vermicompost. The use of post bio-methanated bio-compost showed comparatively higher values over use of raw spent wash. The CEC values ranged from 43.60 (RDF) to 53.98 Cmol (p^{+}) kg^{-1} (PBSW+PMC). The higher value of CEC was observed in PBSW + PMC (53.98) followed by PBSW + STC (51.23 Cmol (p^{+}) kg^{-1}).

The ESP was ranged from 20.12 per cent (control) to 30.95 per cent (RSW + CSC). Among the spent wash bio-compost exchangeable sodium percentage (28.39 per cent) and EMP (27.61 per cent) values were significantly decreased in the treatment of PBSW + PMC. There was significant increase in exchangeable sodium percentage values by use of spent wash bio-composts over control RDF, FYM and vermicompost was noticed. It could be due to higher sodium content in spent wash which was added through bio-compost. Exchangeable magnesium percentage was ranged from 25.65 (Control) to 32.29 (Vermicompost).

The increase in exchangeable sodium percentage and SAR by use of spent wash /spent wash press mud compost was also reported by Murugraghavan (2002) in case of Vertisol and Alfisol of Coimbatore.

Chang and Li (1988) reported increase in sodium adsorption ratio and exchangeable sodium due to utilization of spent wash.Similar observations were reported by Jadhav and Sawant (1975).

4.11.10 Effect on saturated paste extract (SPE) parameters

A. Normal soil

The result in respect of cations and animals in saturated paste extract in normal soil is given in Table 43. The pH of saturated paste extract (pHs) ranged from 8.02 (PBSW + CSC) to 8.17 (Vermicompost). The use of spent wash bio-compost significantly decreased the pHs as compared to control and RDF.The use of PBSW comparatively increased the pHs value as compared to use of raw spent wash.

The EC of saturation paste extract (ECe) ranged from 1.19 (Vermicompost and RDF) to 1.31 (PBSW+ STC and RSW +WSC). The use of PBSW significantly increased the ECe as compared to control, RDF, FYM and Vermicompost.The increase in EC could be due to existence of salt load in spent wash.

The data in respect of cations and anions composition of saturation paste extract (Table 44) indicated that the application of different spent wash bio-compost significantly increased the Ca^{2+},

Table 44. Effect of spent wash bio-compost application on composition of saturation paste extract after harvest of sugarcane in normal soil

Sr. No.	Treatment	pHs	ECe	------------------------Saturation paste extract-------------							SAR
				Cations				Anions			
				Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{-}	Cl^{-}	SO_4^{2-}	
				----------------------------meL^{-1}--------------------------							
1.	AC	8.16	1.22	8.65	7.32	0.16	10.16	4.66	11.35	10.35	3.60
2.	RSW+BC	8.09	1.28	12.87	7.80	0.27	11.07	5.47	14.66	12.34	3.44
3.	PBSW+BC	8.11	1.24	11.59	7.64	0.30	11.87	5.12	14.64	13.07	3.83
4.	RSW+STC	8.08	1.31	13.32	7.74	0.26	12.34	5.50	14.16	13.01	3.80
5.	PBSW+STC	8.13	1.29	12.08	7.55	0.30	12.07	4.23	14.68	12.86	3.86
6.	RSW+PMC	8.11	1.30	13.02	7.88	0.26	11.87	4.20	13.80	13.38	3.68
7.	PBSW+PMC	8.13	1.27	12.15	7.68	0.34	12.05	3.27	14.03	12.81	3.83
8.	RSW+WSC	8.10	1.31	12.20	7.73	0.25	12.65	4.91	13.69	12.86	4.01
9.	PBSW+WSC	8.12	1.28	11.85	7.65	0.30	12.77	4.33	12.74	14.17	4.09
10.	RSW+PeBWC	8.09	1.29	12.99	7.75	0.24	12.50	4.27	13.03	13.58	3.89
11.	PBSWC+PeBWC	8.12	1.26	11.78	7.66	0.28	12.45	4.06	14.09	13.52	3.99-
12.	RSW+CSC	8.09	1.30	12.75	7.78	0.30	12.04	4.41	14.32	12.84	3.76
13.	PBSW+CSC	8.02	1.27	12.07	7.60	0.31	12.92	4.34	14.39	13.11	4.12
14.	FYM (AST)	8.17	1.21	8.72	7.44	0.27	12.82	4.28	12.74	11.36	4.51
15.	VC (AST)	8.17	1.19	8.75	7.48	0.33	12.52	4.32	11.61	11.34	4.40
16.	RDF (AST)	8.16	1.19	8.64	7.52	0.33	10.16	4.40	11.97	11.02	4.45
	SE ±	0.006	0.006	0.302	0.144	0.008	0.415	0.082	0.508	0.444	0.133
	CD at 5 %	0.018	0.018	0.87	NS	0.022	1.199	0.236	1.468	1.283	0.386
	Initial	8.15	1.25	8.66	7.35	0.17	10.15	4.65	11.40	10.32	3.62

K^+, Na^+, Cl^- and $SO^{2-}{}_4$ content of saturation paste extract over control and RDF. The result of Mg^{2+} was non-significant. There was no specific trend for sodium adsorption ratio and HCO_3^- content in saturation paste extract. The sodium adsorption ratio values ranged from 3.44 to 4.51 indicating low salinity development by application of spent wash bio-compost and manures during the first year of its application.

B. Sodic soil

The result in respect of cations and anicns of saturated paste extract sodic soil is given in Table 45

The pH of saturated paste extract (pHs) was ranged from 8.66 (RSW + PeBSW) to 8.77 (PBSW+ PMC)).ECe ranged from 2.69 (RDF) to 3.66 (RSW+PMC).The use of spent wash bio-compost significantly increased ECe values as compared to control, RDF, FYM and vermicompost. The increase in ECe value could be due to presence of salt load in spent wash bio-compost.

The content of Ca^{2+}, Mg^{2+}, HCO_3^- , Cl^- and SO_4^{2-} was significantly increased due to application of spent wash bio-compost over control and RDF. The Na^+ and sodium adsorption ratio values were decreased as compared to control and RDF. The use of press mud, sugarcane trash and chickpea straw bio-compost showed comparatively lower value of SAR than other composts. The use of pearl millet straw, PMC, WCS bio-composts showed increase in $S04^{2-}$ in saturation paste extract under sodic soil condition. The results indicated that use of bio-compost showed ameliorating effect due to presence sulphur and might have enhanced the soil aggregation properties due to higher soluble salts which might have improved drainability of soil due to addition of spent wash bio-compost in sodic soil.

Table 45. Effect of spent wash bio-compost application on composition of saturation paste extract after harvest of sugarcane in sodic soil

Sr. No.	Treatment	pHs	ECe	Saturation paste extract							SAR
				Cations				Anions			
				Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	HCO_3^{2-}	Cl^{-}	SO_4^{2-}	
				meL^{-1}							
1.	AC	8.74	2.71	3.77	1.73	0.30	20.35	4.55	9.22	10.39	12.28
2.	RSW+BC	8.69	3.62	5.27	2.10	0.56	18.21	5.32	11.77	14.70	9.50
3.	PBSW+BC	8.70	3.59	6.30	2.42	0.60	15.49	4.90	10.43	12.13	7.44
4.	RSW+STC	8.70	3.56	5.43	2.15	0.60	17.45	5.68	12.68	14.97	8.97
5.	PBSW+STC	8.73	3.53	6.50	2.48	0.61	15.90	4.29	10.69	12.53	7.51
6.	RSW+PMC	8.69	3.66	5.83	2.55	0.62	17.24	5.61	12.90	15.72	8.44
7.	PBSW+PMC	8.77	3.60	6.93	2.75	0.65	16.23	4.62	10.68	12.70	7.38
8.	RSW+WSC	8.68	3.32	5.23	2.04	0.55	18.40	5.97	12.17	15.52	9.66
9.	PBSW+WSC	8.73	3.28	6.33	2.52	0.60	16.35	4.63	10.33	11.90	7.78
10.	RSW+PeBWC	8.66	3.45	5.43	2.23	0.55	19.45	5.84	12.92	15.36	9.94
11.	PBSWC+PeBWC	8.70	3.39	6.13	2.62	0.58	17.20	4.97	10.59	15.12	8.23
12.	RSW+CSC	8.67	3.43	5.60	2.15	0.59	19.27	5.89	12.61	15.46	9.79
13.	PBSW+CSC	8.70	3.40	6.40	2.62	0.53	16.30	4.62	10.75	12.38	7.82
14.	FYM (AST)	8.74	2.70	4.57	1.90	0.35	20.45	4.17	9.29	10.66	11.38
15.	VC (AST)	8.75	2.71	4.94	2.03	0.39	21.40	4.30	8.78	10.66	11.47
16.	RDF (AST)	8.75	2.69	3.73	2.15	0.36	19.60	4.23	8.84	10.62	11.41
	SE ±	0.008	0.01	0.094	0.052	0.014	0.513	0.093	0.236	0.281	0.267
	CD at 5 %	0.022	0.038	0.272	0.152	0.040	1.481	0.269	0.681	0.812	0.770
	Initial	8.75	2.70	3.80	1.72	0.31	20.25	4.52	9.20	10.35	12.19

4.12 Effect of spent wash bio-compost application on soil biological properties after harvest of *suru* sugarcane

The effect of spent wash bio-compost application on soil microbial count after harvest of sugarcane crop in normal and sodic soil is presented in Tables 46 and 49.

4.12.1 Effect on bacterial, fungal and actinomycetes population

A. Normal soil

The result showed that the bacterial population of soil was increased significantly in all the treatments of application of bio compost over control and RDF. The treatment of post bio-methanated chickpea compost showed significant higher bacterial count (29.77 x 10^6 CFU g^{-1} soil) over all other treatment followed by use of post bio-methanated press mud bio-compost (27.85 x 10^6 CFU g^{-1} soil).

The highest fungal count was noticed in post bio-methanated PMC compost application (14.94 x 10^4 CFU g^{-1} soil) followed by application of post bio-methanated chickpea straw compost (14.05 x 10^4 CFU g^{-1} soil).

The actinomycetes count was significantly increased due to application of post bio-methanated spent wash compost with PMC (27.14 x 10^5 CFU g^{-1} soil).

B. Sodic soil

The data in respect of microbial count is presented in Table 48. The results revealed that, under sodic soil condition the application of RSW + WSC compost showed significantly highest bacterial count (14.77 x 10^6 CFUg^{-1} soil) followed by application of bio-compost prepared from RSW + chickpea (14.66 x 10^6 CFUg^{-1} soil). The actinomycetes count was highest in PBSW + PMC (6.35 x 10^5 CFU g^{-1}) followed by Vermicompost (5.79 x 10^5 CFU g^{-1}). There was significantly the highest fungal count (6.17 x 10^4 CFU g^{-1} soil) recorded in PBSW + PMC followed by RSW+Pe BWC (5.98 X10^4 CFU g^{-1} soil).

In general, soil microbial population was significantly increased due to application of spent wash bio-compost as compared to control, and RDF. Similar observations were also recorded by several workers (Saliha *et al.* 2003, Mallika, 2003, Bhasker *et al.* 2005 and Gore, 2009).

Table 46. Effect of spent wash bio-compost application on soil biological properties after harvest of *suru* sugarcane in normal soil

Sr. No.	Treatment	Soil biological properties		
		Bacteria (x 10^6 CFU g^{-1} soil)	Fungi (x 10^4 CFU g^{-1} soil)	Actinomycetes (x 10^5 CFU g^{-1} soil)
1.	AC	16.08	13.23	12.69
2.	RSW+BC	24.43	14.14	19.66
3.	PBSW+BC	25.52	14.17	22.12
4.	RSW+STC	20.48	12.95	23.74
5.	PBSW+STC	25.78	14.01	24.42
6.	RSW+PMC	25.76	13.92	25.07
7.	PBSW+PMC	27.85	14.94	27.14
8.	RSW+WSC	24.63	13.53	23.65
9.	PBSW+WSC	26.89	14.76	24.76
10.	RSW+PeBWC	23.03	12.74	18.29
11.	PBSWC+PeBWC	25.79	13.81	20.55
12.	RSW+CSC	26.87	13.08	21.80
13.	PBSW+CSC	29.77	14.05	22.61
14.	FYM (AST)	27.81	13.01	20.04
15.	VC (AST)	28.33	13.37	18.12
16.	RDF (AST)	19.10	12.80	13.68
	SE ±	0.55	0.46	0.65
	CD at 5 %	1.59	1.33	1.88
	Initial	22.0	12.50	17.20

Table 47. Effect of spent wash bio-compost application on soil biological properties after harvest of *suru* sugarcane in sodic soil

Sr. No.	Treatment	Soil biological properties		
		Bacteria (x 10^6 CFU g^{-1} soil)	Fungi (x 10^4 CFU g^{-1} soil)	Actinomycetes (x 10^5 CFU g^{-1} soil)
1.	AC	9.96	3.23	3.65
2.	RSW+BC	12.32	4.40	4.94
3.	PBSW+BC	13.46	5.62	5.16
4.	RSW+STC	13.21	5.88	4.58
5.	PBSW+STC	13.83	4.41	5.77
6.	RSW+PMC	13.51	6.17	5.11
7.	PBSW+PMC	14.77	5.44	6.35
8.	RSW+WSC	12.93	5.80	4.14
9.	PBSW+WSC	14.03	5.98	5.18
10.	RSW+PeBWC	12.15	5.43	5.46
11.	PBSWC+PeBWC	14.66	5.57	4.67
12.	RSW+CSC	12.80	5.09	4.99
13.	PBSW+CSC	13.86	5.62	5.49
14.	FYM (AST)	13.82	5.48	5.79
15.	VC (AST)	12.91	4.86	4.68
16.	RDF (AST)	13.77	4.28	4.26
	SE ±	0.44	0.18	0.23
	CD at 5 %	1.27	0.52	0.65
	Initial	10.22	3.50	3.60

4.13 Effect of spent wash bio-compost application on nitrogen mineralization

A. Normal soil

The data presented in table 48 (Fig. 14 and 15) indicated that, use of press mud bio-compost prepared from post bio-methanated spent wash showed, highest NH_4-N and NO_3-N released from 0 to 120 days followed by chickpea compost. The use of raw spent wash showed significantly lower values of NH_4-N and

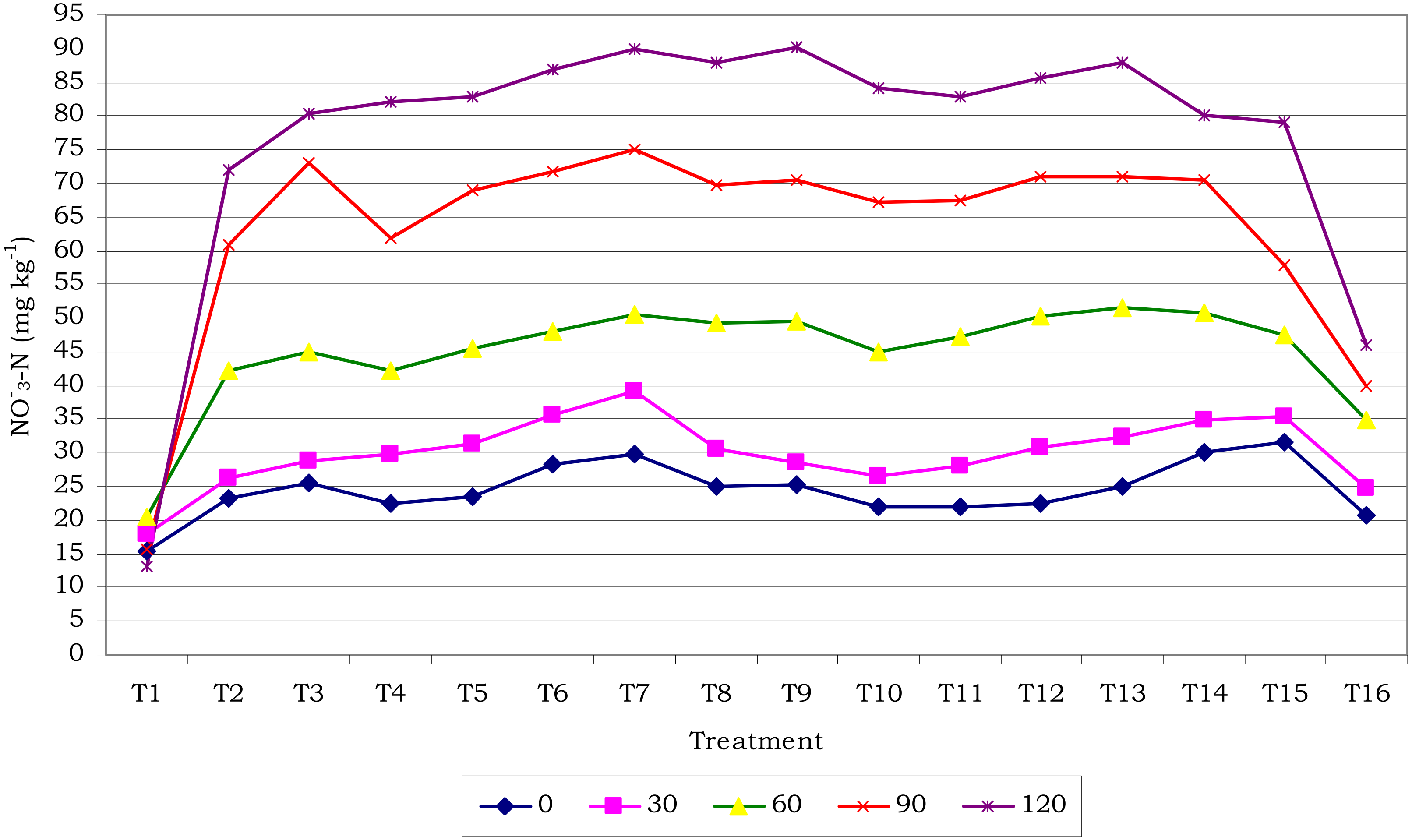

Fig. 14. Effect of spent wash bio-compost application on N mineralization (NO_3-N) in normal soil

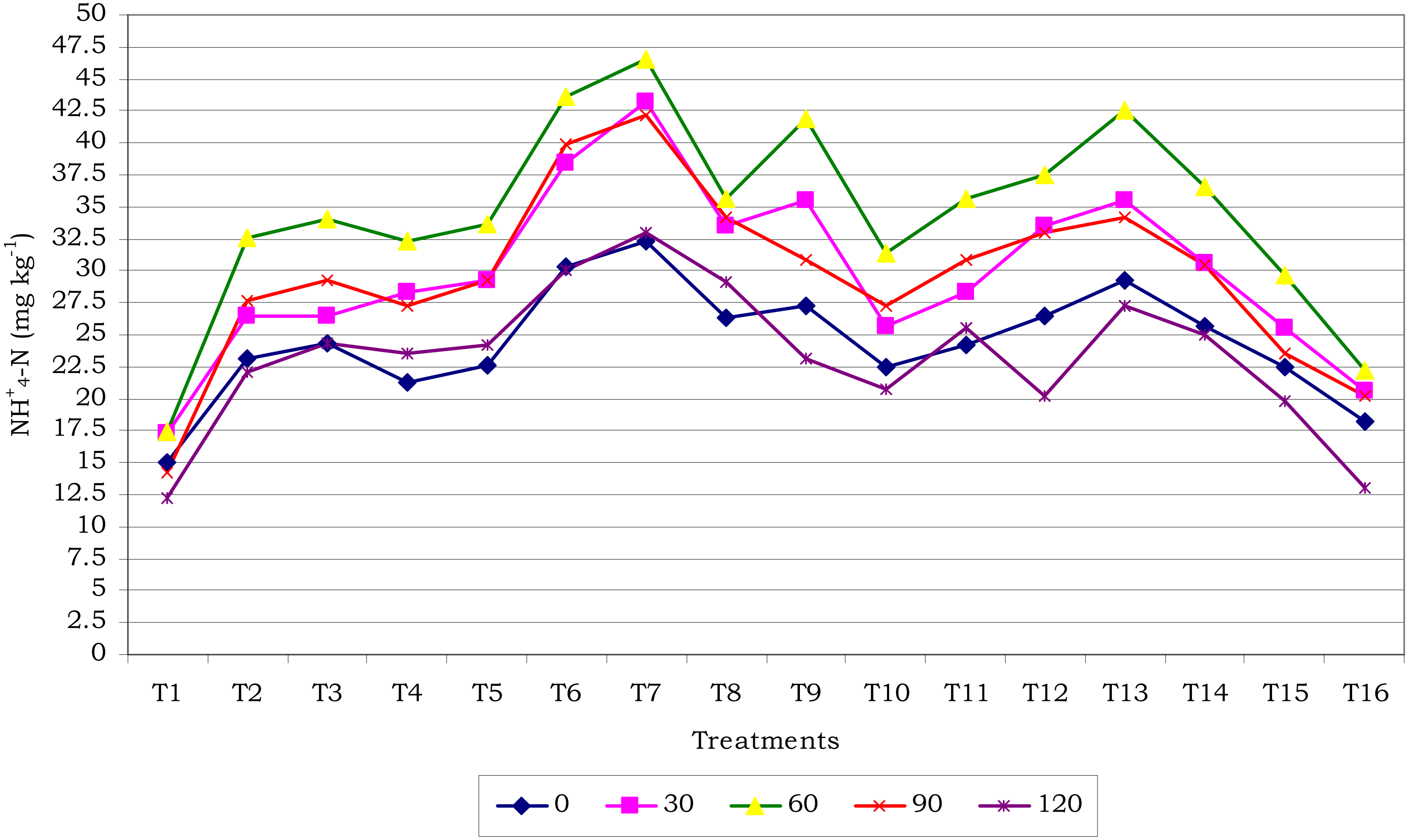

Fig. 15. Effect of spent wash bio-compost application on N mineralization (NH_4^+-N) in normal soil

Table 48. Effect of spent wash bio-compost application on nitrogen mineralization in normal soil

Sr. No	Treatment	NO^-_3- N (mg kg^{-1})					NH^+_4 N (mg kg^{-1})				
		No. of days of incubation					No. of days of incubation				
		0	30	60	90	120	0	30	60	90	120
1.	AC	15.34	18.05	20.35	15.62	13.13	15.08	17.25	17.48	14.28	12.17
2.	RSW+BC	23.34	26.39	42.14	60.90	72.08	23.08	26.40	32.63	27.63	22.08
3.	PBSW+BC	25.58	28.72	44.86	73.08	80.25	24.32	26.49	34.00	29.25	24.27
4.	RSW+STC	22.38	29.73	42.18	61.81	82.05	21.31	28.33	32.29	27.22	23.48
5.	PBSW+STC	23.55	31.26	45.57	68.87	82.88	22.67	29.30	33.60	29.27	24.25
6.	RSW+PMC	28.42	35.69	48.13	71.82	87.00	30.33	38.46	43.62	39.86	30.11
7.	PBSW+PMC	29.78	39.13	50.60	75.02	89.93	32.26	43.20	46.53	42.16	33.03
8.	RSW+WSC	25.09	30.63	49.17	69.65	88.05	26.34	33.53	35.64	34.17	29.18
9.	PBSW+WSC	25.38	28.64	49.45	70.55	90.22	27.24	35.50	41.94	30.80	23.19
10.	RSW+PeBWC	21.98	26.41	44.98	67.23	84.01	22.43	25.62	31.41	27.30	20.75
11.	PBSWC+PeBWC	22.06	28.17	47.35	67.51	82.76	24.25	28.37	35.63	30.79	25.50
12.	RSW+CSC	22.61	30.71	50.34	70.93	85.58	26.48	33.51	37.47	32.96	20.25
13.	PBSW+CSC	24.90	32.41	51.51	70.92	87.84	29.29	35.54	42.55	34.18	27.31
14.	FYM (AST)	30.15	34.88	50.80	70.48	80.20	25.60	30.61	36.63	30.41	25.02
15.	VC (AST)	31.67	35.37	47.48	57.86	79.16	22.53	25.48	29.59	23.54	19.87
16.	RDF (AST)	20.71	24.76	34.98	39.83	45.87	18.25	20.57	22.15	20.24	13.05
	SE ±	0.38	0.47	0.48	0.93	0.79	0.10	0.14	0.55	0.25	0.37
	CD at 5 %	1.11	1.35	1.39	2.68	2.28	0.30	0.40	1.58	0.71	1.07

NO_3-N release over post bio-methanated compost. The NH_4-N concentration steadily increased upto 60 days and there after declined upto 120 days whereas NO_3-N concentration steadily increased upto 120 days. In general, use of spent wash bio-compost prepared from different crop residues showed significantly higher release of NH^+_4-N and NO^-_3-N over RDF and control treatments.

B. Sodic soil

The result in respect of sodic soil is given in Table 49 (Fig. 16 and 17). The NH_4^-N release was higher by use of spent wash bio-compost as compare to control and RDF at all the incubation days. The NH_4^-N was released steadily upto 60 days there after it declined upto 120 days, where as NO_3-N steadily increased from 0 to 120 days. The use of chickpea straw compost prepared from post bio-methanated spent wash released highest NO_3-N at 30, 60, 90 days of incubation. In general, the use of spent wash compost showed comparatively higher NO_3-N release over control and RDF. Similarly, the use of raw spent wash resulted in comparatively lower release of NO_3^-N and $NH^+_4{}^-$N. Release of NO_3-N in sodic soil was higher than normal soil throughout the incubation period (0-120 days). The mineralization study was also reported by Patil (1994) and Jadhav (1994) with spent wash slurry indicated the higher release of NH_4-N and NO_3-N as compared with FYM.Similar observations were recorded by Patil (1994) and Takate (1992).

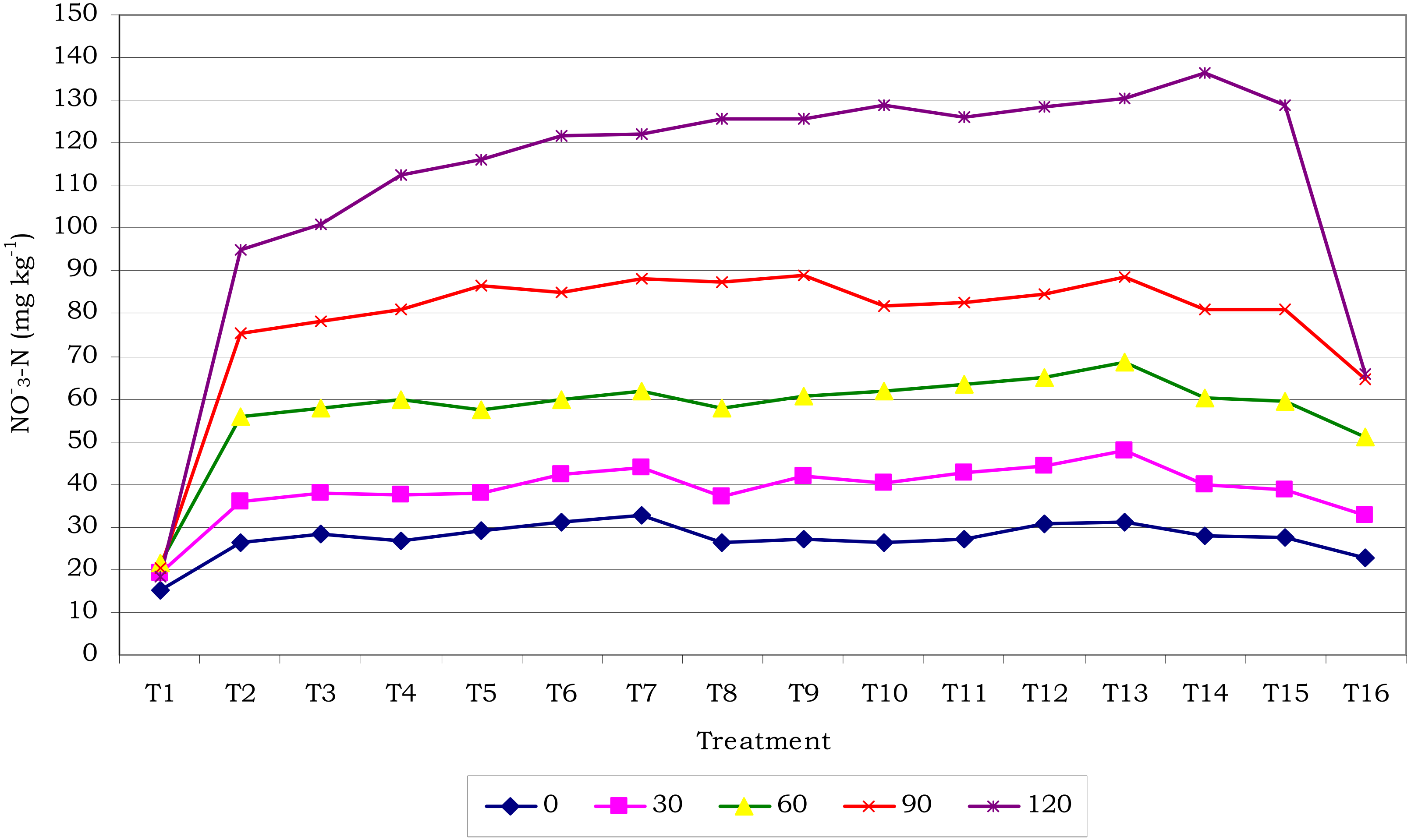

Fig. 16. Effect of spent wash bio-compost application on N mineralization(NO_3-N) in sodic soil

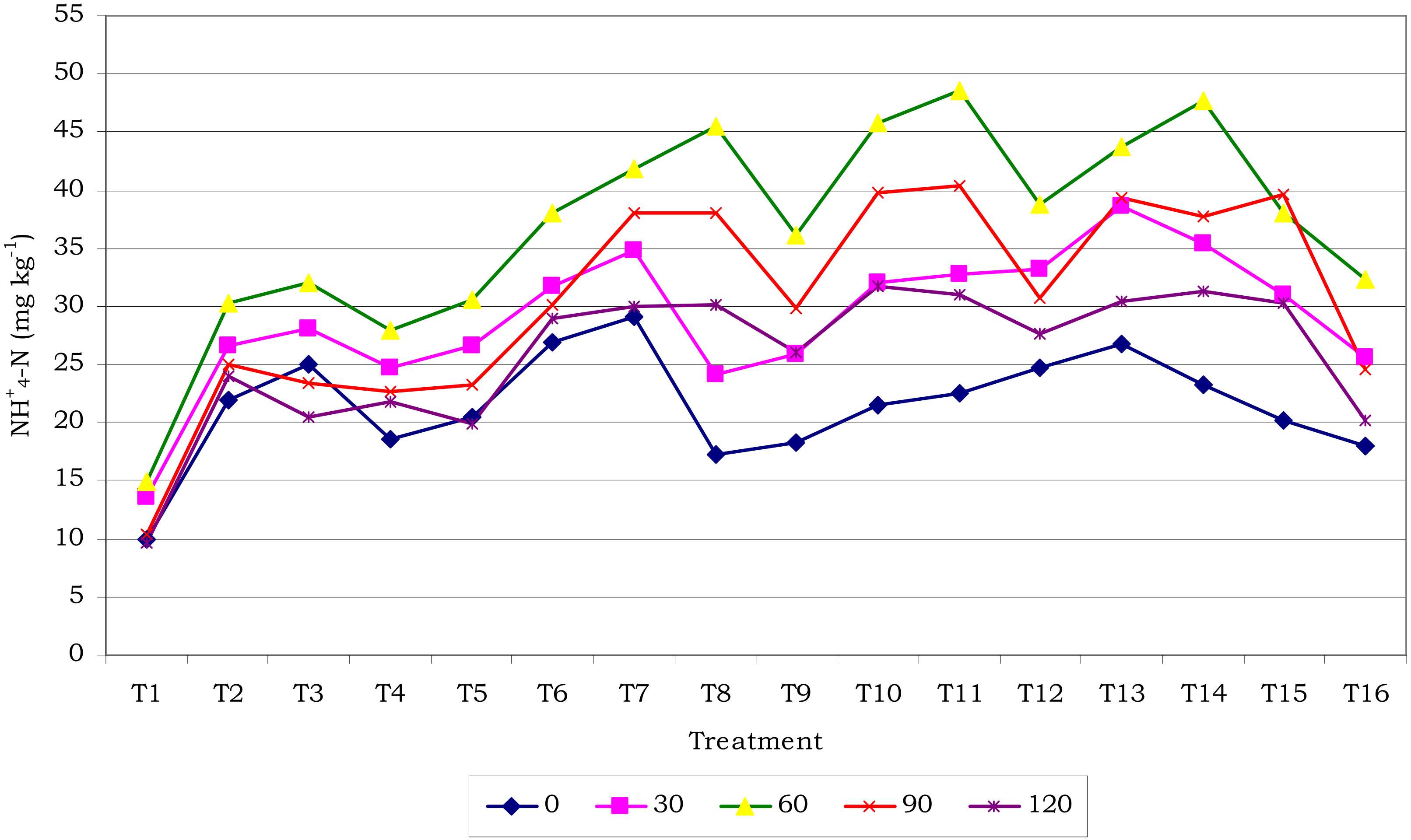

Fig. 17. Effect of spent wash bio-compost application on N mineralization(NH_4^+-N) in sodic soil

Table 49. Effect of spent wash bio-compost application on nitrogen mineralization in sodic soil

Sr. No.	Treatment	NO_3^-- N (mg kg^{-1})					NH_4^+ N (mg kg^{-1})				
		No. of days of incubation					No. of days of incubation				
		0	30	60	90	120	0	30	60	90	120
1.	AC	15.23	19.17	21.63	20.37	18.20	9.88	13.55	14.85	10.43	9.67
2.	RSW+BC	26.27	36.10	55.90	75.47	95.00	22.00	26.62	30.27	25.07	24.04
3.	PBSW+BC	28.33	37.76	58.00	78.27	100.83	24.98	28.03	32.01	23.43	20.43
4.	RSW+STC	26.67	37.64	59.76	80.80	112.50	18.65	24.77	27.99	22.70	21.77
5.	PBSW+STC	29.27	37.97	57.47	86.63	115.97	20.46	26.58	30.58	23.33	19.88
6.	RSW+PMC	31.20	42.20	59.81	84.87	121.70	26.93	31.73	38.05	30.11	28.92
7.	PBSW+PMC	32.57	43.82	61.86	88.00	121.97	29.08	34.81	41.87	38.10	29.92
8.	RSW+WSC	26.15	36.91	57.74	87.30	125.47	17.31	24.15	45.43	38.03	30.08
9.	PBSW+WSC	27.17	41.73	60.77	88.83	125.83	18.28	25.96	36.08	29.90	26.07
10.	RSW+PeBWC	26.39	40.23	62.01	81.60	128.97	21.50	32.05	45.81	39.85	31.67
11.	PBSWC+PeBWC	27.00	42.51	63.52	82.70	125.97	22.52	32.75	48.61	40.32	31.00
12.	RSW+CSC	30.58	44.18	65.18	84.57	128.37	24.74	33.16	38.80	30.75	27.67
13.	PBSW+CSC	31.15	47.93	68.66	88.63	130.63	26.83	38.64	43.77	39.40	30.44
14.	FYM (AST)	28.03	39.76	60.10	81.00	136.47	23.27	35.42	47.62	37.73	31.33
15.	VC (AST)	27.67	38.68	59.28	80.80	129.00	20.23	31.00	38.10	39.60	30.33
16.	RDF (AST)	22.60	32.58	51.08	64.77	65.73	17.98	25.58	32.32	24.52	20.22
	SE ±	0.35	0.46	0.63	0.33	0.76	0.41	2.95	1.80	0.65	0.41
	CD at 5 %	1.02	1.34	1.83	0.96	2.20	1.19	8.52	5.19	1.87	1.89

5. SUMMARY AND CONCLUSIONS

The field experiment was conducted at Post Graduate Institute Research Farm, Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, Dist. Ahmednagar (M.S.) during year 2007-08. The *Suru* (Seasonal) sugarcane (cv. CO-86032) was planted on Typic haplustert (Normal Soil) and sodic haplustert (Sodic Soil). The spent wash bio-composts were prepared from different crop residues *viz.,* Baggasse, sugarcane trash, press mud cake, wheat cut straw, Pearlmillet, chickpea straw with utilizing raw spent wash and post bio-methanated spent wash by heap method. The effects of the spent wash bio-compost along with FYM and Vermicompost were evaluated for sugarcane growth, cane and top yield, juice quality, N, P, K and micro nutrient uptake, soil physical, chemical and biological properties, and N mineralization studies. The results obtained are summarized under different sub heads.

5.1 Characterization of different crop residues/organic sources.

5.2 Characterization of raw and post bio-methanated spent wash

5.3 Characterization of different spent wash bio-compost and manures

5.4 Sugarcane growth parameters

5.5 Sugarcane yield study

5.6 Sugarcane juice quality

5.7 NPK and micronutrients uptake study.

5.8 Soil analysis for its physical, chemical and biological properties.

5.9 Nitrogen mineralization study

5.1 Characterization of different crop residues/organic sources

Among the different crop residues the highest C:N ratio was observed in sugarcane trash (125:1) followed by pearl millet straw (120:1) and baggasse (80.4:1).The chickpea straw showed lowest C:N ratio (40:1) followed by press mud cake (50 :1). Chick pea straw was highest in nitrogen content (0.90 per cent) followed by press mud cake (0.80 per cent). Highest P content was noticed in press mud cake (1.30 per cent) whereas pearl millet straw showed highest total K content (1.30 per cent). Comparatively PMC showed higher Fe (3308 mg kg^{-1}), Zn (251 mg kg^{-1}) and Cu (110 mg kg^{-1}) content.

5.2 Characterization of raw and post bio-methanated spent wash

A. Raw spent wash

The raw spent wash was very dark coffee brown colour with very unpleasant odour. The pH was strongly acidic (4.2) with very high content of soluble salts, EC (19.85 dSm^{-1}), very high BOD (32000 mg L^{-1}) and COD (91000 mg L^{-1}). The total NPK content was 1100, 30.85 and 8800 mg L^{-1}, respectively. The soluble cations were calcium (1890 mg L^{-1}) sodium (850 mg L^{-1}) and magnesium were (1035 mg L^{-1}) observed. The anions were chloride (4200 mg L^{-1}) and sulphate (5400 mg L^{-1}). The micronutrient cations were Fe, Mn, Zn and Cu with concentration of 250, 10.35, 4.20 and 0.75 mg L^{-1}, respectively.

B. Post bio-methanated spent wash

The post bio-methanated spent wash was dark reddish in colour with unpleasant odour, neutral pH (7.2), the EC was

12.55 dSm^{-1}, comparatively low BOD (4400 mg L^{-1}) and COD (25000 mg L^{-1}).

The total NPK content was 850, 10.25 and 6000 mg L^{-1}, respectively with presence of Na^{+} (180 mg L^{-1}) chloride (3520 mg L^{-1}) and sulphate (2200 mg L^{-1}). The micronutrient cations *viz.,* Fe (25.30 mg kg^{-1}), Mn (9.70 mg kg^{-1}), Zn (1.30 mg kg^{-1}) and Cu (0.52 mg kg^{-1}) were noticed.

5.3 Characterization of different spent wash bio-composts and manures

The pH and electrical conductivity were steadily increased at 60, 90 and 120 days in all the bio-composts prepared from different crop residues. The bio-compost prepared from raw spent wash showed comparatively less pH and higher EC than post bio-methanated spent wash.

The use of raw and post bio-methanated spent wash in PMC and chickpea straw showed comparatively higher organic 'C' content at 30, 60, 90 and 120 days of decomposition as compared with other crop residues.

The PBSW + PMC showed comparatively higher nitrogen (1.13 per cent), P (0.83 per cent), K (1.12 per cent) and sulphur (0.82 per cent) as compared with other bio-composts.

The C:N ratio of spent wash bio-compost was continuously declined from 30, 60, 90 and 120 days of decomposition stage. PBSW + PMC showed lower values of C:N ratio (16.39), C:P ratio (22.31) and C:S ratio (22.59) with highest content of humic acid (8.6 per cent) and fulvic acid (26.30 per cent). Where as RSW + PMC showed higher Fe (4435 mg kg^{-1}) and Mn (482 mg kg^{-1}) content. However, highest Cu (75 mg kg^{-1}) and Zn (210 mg kg^{-1}) content was observed in RSW + STC bio-compost.

5.4 Sugarcane growth parameters

The effect of application of post bio-methanated PMC composts and chickpea compost comparatively showed better growth parameters in respect of tillering ratio, cane height and cane girth and number of millable canes under normal and sodic soil conditions respectively.

5.5 Sugarcane yield

Among the different spent wash bio- compost tested, the application of PBSW + PMC bio-compost significantly increased the cane yield (109 t ha^{-1}) in normal soil followed by PBSW + CSC (101 t ha^{-1}) where as in sodic soil the highest sugarcane yield was recorded (87.20 t ha^{-1}) due to application of PBSW + PMC followed by RSW+PMC (83.15 t ha^{-1}) and PBSW + CSC (80.8 t ha^{-1}).

The sugarcane top yield was significantly higher due to application PBSW + PMC (9.81 t ha^{-1}) in normal soil as well as in sodic soil (8.34 t ha^{-1}) followed by raw spent wash + PMC bio-compost (7.95 t ha^{-1}).

5.6 Sugarcane juice quality

Reducing sugar and CCS yield (t ha^{-1}) were significantly increased due to application of bio-compost over RDF and control. The highest CCS yield was recorded in PBSW + PMC (14.37 t ha^{-1}) followed by PBSW+ CSC (13.16 t ha^{-1}). The PBSW + PMC showed highest reducing sugar content (0.35 per cent) in normal soil.

The highest content of sucrose was noticed in treatment RSW + WSC (20.94 per cent).The bio-compost prepared from press mud cake and chickpea straw showed comparatively higher CCS yield over RDF, FYM and vermicompost in sodic soil.

5.7 NPK and micronutrients uptake.

The use of either raw spent wash or post bio-methanated compost prepared from different crop residues showed significantly higher NPK uptake over RDF and control in normal soil.

The use of post bio-methanated spent wash bio-compost showed significantly higher NPK uptake as compared to raw spent wash bio-compost in sodic soil.

Among the bio-compost, PBSW + PMC and PBSW + CSC showed higher uptake of Fe, Mn, Cu and Zn uptake over FYM and vermicompost in normal and sodic soil.

5.8 Soil analysis for its physical, chemical and biological properties

In normal soil, the textural properties did not influenced significantly due to application of spent wash bio-compost and manures. The applications of bio-composts significantly decreased the bulk density of soil as compared with control and RDF. Use of post bio-methanated spent wash chickpea straw bio-compost showed lowest soil bulk density (1.31 Mg m^{-3}) followed by press mud compost (1.32 Mg m^{-3}). The use of bio-compost significantly increased the hydraulic conductivity over control and RDF. The significant decrease in dispersion index was observed due to application of spent wash bio-composts over control and RDF.

The application of RSW+ PMC compost showed the lowest soil pH (8.10). The soil pH was increased where post bio-methanated spent wash was used. The use of post bio-methanated spent wash, bio-compost showed comparatively lower EC values than raw spent wash bio-compost. Among the treatments, PBSW + PMC showed significantly higher organic carbon content followed by RSW + PMC.

Higher available nitrogen (224.33 kg ha^{-1}) was recorded in the treatment of post bio-methanated spent wash + chickpea straw compost followed by PBSW+ PMC (222.33 kg ha^{-1}). The available P content was significantly increased by application of RSW + chickpea straw bio-compost. The highest available K content (763 kg ha^{-1}) was reported in RSW + pearl millet straw compost treated plot over FYM. The significant built up of exchangeable K^+ was observed, by use of spent wash bio-composts over FYM and vermicompost. The use of spent wash bio-compost significantly decreased the pHs as compared to control and RDF.

The bulk density of sodic soil under different treatments ranged from 1.33 to 1.39 Mg m^{-3}. The application of spent wash composts showed significant improvement in HC over control, RDF, FYM and vermicompost treatments in sodic soil. The slight decrease in dispersion index was observed due to application of spent wash bio-composts over control and RDF. Mean weight diameter of water stable aggregate of sodic soil was improved significantly due to addition of spent wash bio-composts over control and RDF. The application of RSW + STC, RSW + PMC, RSW + WCS showed significantly lower soil pH (8.70) as compared with RDF, FYM and vermicompost. Raw spent wash bio-compost treated plots showed higher EC as compared to PBSW, control, FYM, vermicompost and RDF treated plots. The significantly higher organic carbon content was recorded in the treatment of PBSW + CSC followed by PBMSW + PMC.

The application of spent wash bio-compost showed significant improvement in available status of NPK as compared to RDF. The application of spent wash bio-compost significantly increased the exchangeable cations under normal and sodic soil condition. The significant increase in soil ESP was noticed by use of spent wash bio-composts over control RDF, FYM and vermicompost treated plot.

5.9 Effect of spent wash bio-compost on saturation paste extract in normal soil

The application of different spent wash bio-compost significantly increased the Ca^{2+}, K^{+}, Na^{+}, Cl^{-} and $SO_4^{-\ 2}$content of saturation paste extract over control and RDF. There was no specific trend for SAR and HCO^{-}_3 content. The application of spent wash bio-compost indicated low salinity development during the first year. The SO_4^{2-} concentration in soil solution was increased specifically in WCS, PMC, pearl millet straw and chickpea straw.

5.10 Nitrogen mineralization study

Use of spent wash bio-compost prepared from different crop residues showed significantly higher release of NH^{+}_4-N and NO_3-N over RDF and control treatments under normal and sodic soil condition.

The use of spent wash compost showed comparatively higher NO_3-N release over control and RDF. Similarly, the use of raw spent wash resulted in comparatively lower release of NO_3^{-}N and $NH^{+}_4{}^{-}$N under normal and sodic soil condition.

Conclusions

1. The post bio-methanated spent wash of Kolpewadi co-operative sugar factory Ltd.,Kopergaon had considerably reduced total solids, ash content, EC, BOD and COD, organic carbon , sodium content, colour and increased pH towards neutrality as compared to fresh raw spent wash.
2. Total 3000 litres of fresh (unstored) raw and post bio-metahnated spent wash were mixed in each 1 ton (1:3 ratio) of each different organic sources for preparation of different biocompost.
3. Among the bio-composts prepared from different crop residues with raw and post bio-methanated spent wash, the bio-compost prepared from post bio-methanated spent wash + press mud cake showed lowest C:N, C:P and C:S ratio with higher CEC, Fe, Zn, humic and fulvic acid content. The highest C: N ratio was observed in sugarcane trash (125:1) followed by pearl millet straw (120:1) and baggasse (80.4:1). The chickpea straw showed lowest C: N ratio (40:1) followed by press mud cake (50:1).
4. Use of post bio-methanated bio-compost specifically prepared from press mud cake (12.39 t ha^{-1}) and chickpea straw (17.28 t ha^{-1}) showed improvement in bulk density, hydraulic conductivity, dispersion index, not only in sodic soil but also under normal soil condition.
5. Soil chemical properties, nutrient availability and microbial count were improved due to application of bio-compost prepared from post bio-methanated spent wash + press mud cake followed by post bio-methanated spent wash + chickpea straw.

6. Among the bio-compost prepared from different crop residues with raw and post bio-methanated spent wash, application of bio-compost *viz.,* post bio-methanated spent wash + press mud cake showed significantly highest cane yield, CCS yield, total NPK, Fe and Zn uptake under normal soil condition.
7. The application of post bio-methanated spent wash + press mud cake bio-compost showed highest NH^{+}_{4} and NO_3^-N release upto 120 days of incubation period followed by PBSW + chickpea straw compost. Use of raw spent wash bio-compost decreased NH^{+}_{4} + NO_3^-N release as compared to bio-compost prepared from post bio-methanated spent wash
8. Under sodic soil condition application of post bio-methanated spent wash + chickpea straw (17.28 t ha^{-1}) bio-compost showed highest millable canes, cane and CCS yield, NPK and micronutrient uptake than other bio-composts. Thus the post bio-methanated spent wash could be explored with press mud cake or chickpea straw for obtaining better manurial properties. It's utilization could help for improving physical, chemical, microbial properties and bio-nutrient availability to sugarcane under sodic and normal soil conditions.

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*** Originals not Seen**

7. VITA

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DOCTOR OF PHYLOSOPHY

in

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

2012

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