UTILIZATION OF DISTILLERY SPENTWASH FOR RECLAMATION OF SODIC SOIL AND FERTI-IRRIGATION STUDIES IN RICE

BHAGYA LAKSHMI, T.

PAK 6081

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

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BHAGYA LAKSHMI, T.

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BENGALURU **JULY, 2009**

Affectionately

dedicated

to my beloved Parents

&

Chairman

CERTIFICATE

This is to certify that the thesis entitled "**utilization of distillery spentwash for reclamation of sodic soil and ferti-irrigation studies in rice**" submitted by **Miss. Bhagya Lakshmi, T.** for the degree of **DOCTOR OF PHILOSOPHY in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Agricultural Sciences, Bangalore, is a record of research work done by her during the period of her study in this University under my guidance and supervision, and the thesis has not previously formed the basis of the award of any other degree, diploma, associateship, fellowship or similar other titles.

Bangalore
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(C.A. Srinivasamurthy)
Major Advisor

Approved by :

Chairman: (C.A. Srinivasamurthy) 4/9/09

Members:

1. (K.Sudhir)
2. (S. Bhaskar)
3. (A.N. Balakrishna)
4. (C.T.Subbarayappa) 4/9/09

4/9/09
External Examiner
(Dr. M. Ravichandran)

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"UTILIZATION OF SPENTWASH FOR RECLAMATION OF SODIC SOIL AND FERTI-IRRIGATION STUDIES IN RICE"

THESIS ABSTRACT

The raw distillery spentwash samples from M/s Chamundeshwari Distilleries Private Limited, K.M.Doddi, Maddur Taluk, Mandya district revealed that it was highly acidic (pH 4.11), with the electrical conductivity of 17.70 dS m^{-1}. The concentration of nitrogen, phosphorus and potassium were 0.19, 0.03, and 0.88 per cent respectively and also has good amount of calcium and magnesium content of 2600 and 1700 mg L^{-1} respectively.

In the green house experiment I, raw spentwash application @5.0 lakh liters ha^{-1} significantly reduced the pH, exchangeable sodium and ESP of soil at 30 and 60 days after application and the reduction was marginal there after upto 120 days. Application of gypsum @ 100% GR had similar effect in reducing the soil pH and ESP as that with raw spentwash application @ 2.5 lakh liters ha^{-1}.

In the field experiment highest grain and straw yield and nutrient uptake were recorded in raw spentwash @ 5.0 lakh liters ha^{-1} and 7.5 lakh liter $ha^{-1,}$ gypsum amended plots and control recorded lowest yield. Reduction in soil pH ,exchangeable sodium and ESP was maximum in plots receiving 5.0 lakh liters ha^{-1} followed by 7.5 lakh liters ha^{-1} and highest exchangeable calcium and magnesium content was recorded in plots receiving 5.0 lakh liters ha^{-1} followed by 7.5 lakh liters ha^{-1} which was significantly superior over plots receiving gypsum and control.

In the green house ferti-irrigation experiment II, highest yield and nutrient uptake were noticed with application of DSW 150% RDN (in 33% in each irrigation) followed by 150% N through urea in (33% in each irrigation) and RDF (NPK) + FYM.

In the field experiment II ferti-irrigation of primary spentwash on reclaimed sodic soil highest grain, straw yield and nutrient uptake were recorded in RSW @ 100% GR+100% RDN through SW (3splits) and lowest was recorded in T_1 which received gypsum @50% GR + Recommended NPK. Reduction in soil pH, sodium and ESP was maximum in T_9 (RSW @ 100% GR+100% RDN through SW (3splits)) and minimum in T_1 (Gypsum@50% GR+ Rec.NPK).

Signature of Student	Signature of Major Advisor
(Bhagya Lakshmi T)	(C. A. Srinivasamurthy)

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INTRODUCTION

I. INTRODUCTION

Rapid rate of industrialization has accelerated soil and water pollution around the industrial units due to unscientific methods of discharge of waste materials on land or into water bodies. Since industrialization and pollution go together problem of disposal of industrial wastes assume paramount importance. In India molasses based distilleries are considered to be one of the most polluting agro-based industries due to generation of large amount of foul smelling, brown coloured waste water with very high BOD and COD. This waste water is also called as spentwash. Approximately 40 million m^3 of distillery spentwash are discharged annually from 285 alcohol distilleries in India (Susheel Kumar *et al.,* 2007). The problem with most distilleries has been the disposal of spentwash, generated by them since their inception as no fool proof technologies are available for treatment/disposal. The raw spentwash is highly acidic in nature and possess high salt content and higher amounts of dissolved and suspended solids. Discharge of raw spentwash on land or into near by water bodies results in water and soil pollution. Hence discharge of rawspentwash is a great problem.

In India out of 329 million hectares of geographical area, the salt affected soils comprise of 4.5 million hectares of sodic soil. Sodic soils are found to be highly problematic for crop production because of very poor physical and chemical environment particularly in irrigated areas. Excessive use of irrigation water and poor water management practices are the chief causes for waterlogging and salt build up. Sodicity problem in irrigated agriculture is becoming more and more serious because of faulty irrigation practices followed on soils of poor drainage condition or due to use of poor quality water coupled with intensive cultivation of high water requirement crops.

Amelioration of these sodic soils is very much essential as these lands are characterized by adverse physical conditions with high sodium build up and these soils can be put to crop production only when they are reclaimed using amendments. The reclamation of sodic soils basically involves removal of excess sodium on the soil exchange complex with calcium, removal of excess salts and to facilitate stable aggregation of soil particles. Sodic soil reclamation essentially requires a soluble source of calcium whether mobilized from native $CaCO_3$ or added externally as soluble calcium salt.

Gypsum is the most common amendment used for reclamation of sodic soils which serves as a source of calcium. On the other hand pyrites and elemental sulphur are used as an amendment to reclaim calcareous sodic soil. These two amendments solubilise the insoluble calcium carbonate present in these soils and thus bring about reclamation. Utilization of industrial wastes which are either a source of calcium or are capable of generating calcium in soil ,will not only economise the process of reclamation but will also safeguard the environment from its degradation through waste disposal.

Though the spent wash has a high BOD and COD load, also has appreciable quantities of dissolved salts which are mainly chlorides and sulphates of potassium and calcium. This high concentration calcium can be effectively utilized in the reclamation of sodic soil.

Raw spentwash, distillery waste water is quite acidic in nature (pH: 4.0) capable of solublising the native $CaCO_3$ of the calcareous sodic soil and liberates calcium in to soil. It also contains good amount of calcium along with plant nutrients and easily oxidisable organic matter. Thus it can be effectively used as a source of plant nutrients and as a soil amendment.

Studies pertaining to use distillery raw spentwash for reclamation of sodic/calcareous sodic soils are the need of the hour to address the twin problems being faced by distilleries in disposing of this effluent. The research conduted in different parts of world suggests the beneficial effect of spentwash in crop production. Utilization of raw spentwash for reclamation of sodic soil and its consequent effect on soil properties and paddy crop growth and yield, extent of pollution of ground water and also ferti-irrigation studies in paddy using treated spentwash is limited. It was therefore felt necessary to assess the potential of raw spentwash in reclamation of sodic soil and also its effect on soil, water and on paddy crop. Keeping these aspects in view, the present research was conducted with the following objectives,

1) To characterize the distillery spentwash for physical & chemical properties and its nutrients composition.

2) To study and compare the effect of raw distillery spentwash and gypsum on reclamation of sodic soil and their effect on soil properties, growth and yield of paddy.

3) To study the effect of ferti-irrigation of distillery spentwash on soil properties, growth and yield of paddy.

4) To work out the cost economics involved in reclamation of sodic soils and ferti-irrigation of paddy with spentwash.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Molasses one of the important byproducts of sugar industry is the chief source for the production of alcohol in distilleries by fermentation method. About 40 billion liters of waste water annually discharged by distilleries, known as spent wash, is characterized by easily oxidisable organic matter with very high biological oxygen demand and chemical oxygen demand, undesirable color and foul odour. The spentwash is highly acidic and consists of easily oxidisable organic matter with very high BOD and COD. Besides, it has higher concentration of potassium, calcium, magnesium, sulphate and chloride and appreciable quantities of nitrogen, but the concentration of phosphorus is low. Thus it can be used as a source of plant nutrients and as soil amendment for problematic soils.

A brief review of the available literature pertaining to the present investigation has been presented in this chapter under the following headings :

2.1. Characterization of distillery spentwash.

2.2. Characterization of sodic soil.

2.3. Reclamation of sodic soil using different amendments.

2.4. Raw spentwash as an amendment for reclamation of sodic soil.

2.5. Response of cereal crops to ferti-irrigation of spentwash.

2.6. Effect of spentwash on soil properties.

2.7. Effect of spentwash application on ground water quality.

2.1 Characterization of distillery spentwash

Molasses a by-product of sugar industries is being used as raw material in distilleries for the production of alcohol which gives considerable income for these industries. However, for every liter of alcohol produced, about 10-15 liters of waste water (spentwash) is produced which pose major disposal problem. The distillery industrial waste water is non-toxic, biodegradable, purely of plant origin and contains large quantities of soluble organic matter and plant nutrients, which the sugarcane plant has absorbed from the soil. Disposal of spent wash is causing environmental problems due to high BOD and COD but contains valuable macro and micro minerals hence it can be considered as a liquid fertilizer.

Jadhav and Sawant (1975) analyzed the primary treated spentwash for its chemical composition. The value for different constituents were, pH: 8, EC (dS m^{-1}): 31.0, total N: 1,400 mg L^{-1}, total P: 1225 mg L^{-1}, total K: 13600 mg L^{-1}, total Ca: 100 ppm, total Mg: 1,700 mg L^{-1} and COD: 13,000 mg L^{-1}.

Bucknall *et al.* (1979) reported that the potale had a pH of 3.3 and the concentrations of other constituents were; N: 2,080 ppm, P: 700 ppm, K: 1,000 ppm, Mg: 200 ppm and Na: 500 ppm on fresh weight basis.

Robertiellow (1982) analyzed the chemical constituents of vinasse and reported that cane vinasse had a pH of 5.4, BOD of 57,400 mg $L^{-1}$and COD of 1, 03,000 mg L^{-1}. The other constituents were; total N 1190 mg L^{-1} and total P: 120 mg L^{-1}.

Sahai *et al.* (1983) revealed that the distillery effluent contained an excess of various forms of cations and anions, which are injurious to plant growth.The concentration of these constituents should be reduced to beneficial level by diluting the effluent, which can be used as a substitute for chemical fertilizer.

Kulkarni *et al*. (1987) classified spentwash as dilute liquid organic fertilizer with high K content and reported that it contained about 90 to 93 per cent water and 7 to 9 per cent solids. Seventy five per cent of solids were organic and 25 per cent were inorganic. Its N was mostly in colloidal form that behaved as a slow release fertilizer and it was better than other inorganic N source. The two thirds of P was in organic form and the metabolic availability of which was more than any important secondary elements such as Ca, S and Mg as well as Cu, Mn and Zn.

Rajaram and Janardhanan (1988) while studying the effect of distillery effluent on seed germination and seedling growth of rice analyzed the distillery effluent for different constituents. The results revealed that effluent had 18 mg L^{-1} N, 34,650 mg L^{-1} BOD, 1,13,095 mg L^{-1} COD and a pH of 4.7.

Patil *et al.* (1987) reported that raw spentwash was reddish brown to dark brown and possessed an unpleasant smell of burnt or caramelized sugar. It was highly acidic with a pH range of 3.5 to 4.0 and carried a huge organic load (BOD: 4500 to 55,000 mg L^{-1}, COD: 90,000 to 1, 10,000 mg L^{-1}), total solids: 80,000 to 90,000 mg L^{-1}, suspended solids: 300 to 500 mg L^{-1}, volatile solids: 55,000 to 67,000 mg L^{-1}, total nitrogen: 1200 to 1400 mg L^{-1}, phosphorus: 800 to 1200 mg L^{-1}. It also had good amount of potassium (8000 to 13000 mg L^{-1}), chlorides (5000 to 6500 mg L^{-1}) and sulphates (4000 to 8000 mg L^{-1}). Besides, it also contained Na: 1100 to 1400 mg L^{-1}, Ca: 2100 to 3300 mg L^{-1}, Mg: 2000 to 3300 mg L^{-1} and Fe: 50 to 70 mg L^{-1}.

Chang and Li (1989) reported that vinasse contained 16 per cent organic matter and 1 per cent K_2O. Kadioglu and Algur (1990) reported the data on chemical composition of the vinasse with pH value as 5.19 and biological oxygen demand as 63 g L^{-1}.

Anaerobically digested effluent from molasses residue had the elemental concentration of total N: 21,300 mg L^{-1}, P: 4,000 mg L^{-1}, K: 1, 20,000 mg L^{-1}, Ca: 32,000 mg L^{-1}, Mg: 18,000 mg L^{-1} and Na: 14,000 mg L^{-1} (Sweeney and Graetz, 1991).

Peneque *et al.* (1991) analyzed the raw sugar wastewater for its chemical composition and reported that it had pH of 4.4 and electrical conductivity as 6.83 m mhos cm^{-1}.

Bhat (1994) analyzed the distillery effluent of M/s Ugar Sugar Works Ltd., Ugarkhurd and reported that pH of raw spentwash acidic (4.03) which increased to 7.62 during lagooning. It also contained large amounts of suspended and dissolved solids having high concentration of BOD and COD. Whereas, the contents of Ca, Mg and K were higher than Na.

Vaidyanathan *et al.* (1995) stated that spentwash was highly acidic and carried a huge amount of organic load. Different constituent values were total solids: 9000 to 15000 mg L^{-1}, COD: 115000 to 120000 mg L^{-1}, total nitrogen: 1800 to 2000 mg L^{-1} and phosphates: 2000 to 2100. It had a good amount of SO_4 and Cl, 3000 to 4000 and 7000 to 8000 mg L^{-1} respectively.

Joshi *et al.* (1996) found that the distillery effluent contained large amounts of organic matter, N, P, K, S, and Ca. Further, it contained a high salt load, sulfates and chlorides of K, Na and Ca.

Spentwash had a very high EC (29.00 dS m^{-1}) with neutral in reaction (7.20), sodium adsorption ratio 4.17, Ca, Mg, K, NO_3, HCO_3, SO_4 and Cl values were: 58.88, 34.54, 170.87, 28.58, 35.00, 195.25 and 65.50 m mol L^{-1}, respectively. It had total N, P and K content of 1200, 900 and 6681 mg L^{-1}, respectively. Fe, Mn, Zn and Cu contents were 61.26, 4.00, 1.17 and 0.78 mg L^{-1}, respectively. Pb^{2+}, Cd^{2+} and Ni content of spentwash was 0.68, 0.04, 0.70 mg L^{-1}, respectively. In spentwash higher organic loading is the problem, i.e. high BOD and COD of 2500 mg L^{-1} and 6000 mg L^{-1}, respectively (Zalawadia *et al.*, 1997).

Pathak *et al.* (1999) reviewed the data on characteristics of the distillery spentwash. It has a neutral reaction (6.9), alkalinity ($CaCO_3$ 491.3 mg L^{-1}), total dissolved solids (128.0 mg L^{-1}), volatile suspended solids (113.00 mg L^{-1}) with high COD (2152 mg L^{-1}), soluble COD (1740 mg L^{-1}) and BOD at 20 C (1002 mg L^{-1}). Spentwash contained almost all the elements required by the plants like SO_4, Cl, Na, K and Ca, with concentrations of 46.0, 18.5, 100.0, 91.0 and 438.0 mg L^{-1} respectively.

Analytical data of raw distillery effluent collected from M/s Coimbatore Alcohols and Chemicals Ltd. situated on the banks of river Bhavani were reviewed by Kailasam *et. al.* (2001). The parameters were pH (8.57), electrical conductivity (36075 mmhos m^{-3}), total suspended solids (9200 mg L^{-1}), total dissolved solids (10230 mg L^{-1}), chlorides (6748 mg L^{-1}), sulphates (80 mg L^{-1}), biological oxygen demand (1400 mg L^{-1}), chemical oxygen demand (1400 mg L^{-1}), volatile suspended solids (2450 mg L^{-1}) and potassium (4560 mg L^{-1}).

Arafat Sayed and Vassen Abd Elazim (2002) analyzed the vinasse for its chemical characterization and found that that vinasse was acidic in reaction (4.43) with high electrical conductivity (21.0 dS m^{-1}) and organic load. Total s2olids 90.0 g L^{-1}, soluble solids 83.0 g L^{-1} and total COD 100 g L^{-1}, soluble solids 83.0 g L^{-1}, total BOD 39 g L^{-1}. It contained a good amount of total K (0.6per cent), total Ca (0.54per cent), and total Mg (0.27per cent). Organic carbon content was 3.10 per cent, organic matter (6.2per cent), fulvic acid (0.83per cent) and humic acid (0.32 per cent) and also had a total N -1204 mg L^{-1}, ammonical nitrogen - 87 mg L^{-1}, nitrate nitrogen - 182.4 mg L^{-1} with total P - 423 mg L^{-1} and soluble P - 185 mg L^{-1}.

Sukanya and Meli (2005) reported the characteristics and composition of liquid distillery effluent i.e. spentwash, which has dark brown color with unpleasant odour, and pH of 7.8. Adverse effect of distillery effluent was due to very high EC (20.8 dS m^{-1}), total dissolved solids (14635 mg L^{-1}), organic carbon (0.8 per cent), total suspended solids (3800 mg L^{-1}). High organic load resulted in more BOD and COD (4620 and 26000 mg L^{-1} respectively). Total nitrogen: 0.19 per cent, total phosphorus: 6 ppm, total calcium and magnesium: 100 and 200 m moles L^{-1}, respectively. It contained a good amount of potassium (5356 ppm) and iron (38 ppm). Sulphite 4.2 and chloride 14.40 m moles L^{-1}, Na, Zn and Cu content of spentwash were 6.3, 2.0 and 0.4 mg L^{-1}, respectively. Bicarbonate content was 150 mg L^{-1} while, carbonate was not present in spentwash.

Mohamed Haroon and Subash Chandra Bose (2004) studied the chemical composition of untreated distillery spentwash and primary treated distillery spentwash. The results revealed that there was a considerable change in chemical composition of untreated and primary treated spentwash with acidic (3.8) and alkaline (8.0) reaction, respectively. Electrical conductivity of untreated and primary treated spentwash was 30 and 32.5 dS m^{-1}, respectively. Total solids content in untreated and primary spentwash samples was 90,000 and 81,000 (mg L^{-1}), respectively. Other compositions are nitrogen (mg L^{-1}): 1500(untreated) and 1740 (primary), Phosphorus (mg L^{-1}): 260 (untreated) and 260 (primary), potassium (mg L^{-1}): 10000 (untreated) and 11500 (primary), Calcium (mg L^{-1}): 7000 (untreated) and 1050 (primary), magnesium (mg L^{-1}): 3300 (untreated) and 2200 (primary), sodium (mg L^{-1}): 400 (untreated and 510 (primary), chloride (mg L^{-1}):

5000 (untreated) and 11200 (primary) and also sulphate (mg L^{-1}) content of untreated spentwash: 5000 and primary: 2400.

Madhusudhana (2006) reported that primary treated spentwash collected from J. P. Distilleries Pvt. Ltd., Kunigal was neutral in reaction and contained higher amounts of soluble salts(10.59 dS m^{-1}). It had high organic load in terms of BOD (16026 mg L^{-1}) and COD (33368 mg L^{-1}). Among plant nutrients it contained higher potassium (11400 mg L^{-1}) and moderate amount of nitrogen (1200 mg L^{-1}),calcium(1900 mg L^{-1}), magnesium (1500 mg L^{-1}) and sulphur (193 mg L^{-1}) but low phosphorus and micro nutrients.

Suma (2006) analyzed the primary treated spentwash from Chamundi Distilleries, Pvt., Ltd, near Bannur and it was found that spentwash was neutral in reaction and contained high soluble salts (9.18dS m^{-1}) and organic load (BOD-16057 and COD-28674 mg kg^{-1}. Also contained high amount of K (1.15 per cent) and appreciable quantities of N (0.11per cent), Ca (1700 mg kg^{-1}), Mg (1344 mg kg^{-1}) and S (387.8mg kg^{-1})

2.2 Characterization of sodic soil

Soils generally have a pH less than 8.5. In these soils the presence of electrolytes and negative adsorption of anions are known to decrease the thickness of the double layer and suppress the hydrolysis of adsorbed Na^{+}. As a result, the hydroxyl ion concentration goes down, leading to reduced pH (Bear, 1964).Contrarily, lack of neutral salts and predominance of sodium salts capable of alkaline hydrolysis such as carbonate and bicarbonates of sodium, along with others, sodic soils are associated with a high alkalinity characterized by pH as high as 10.5(Szablocs,1993).

Agarwal and Rammoorthy (1970) compared the morphological and chemical properties of alkali and normal soil profiles in both black and red soil regions of India. The results indicated higher chloride-sulphide ratio and nitrogen losses during alkali development in the heavy textured soils of black soil region. Whereas low chloride-sulphate ratio was found in red soil region.

Bhadrapur and Seshagiri Rao (1977) studied salt affected black soil in Tungabhadra command area (Karnataka) which showed lower concentration of sulphates in surface layers compared to chlorides. This was on account of lower mobility and solubility of sulphates of calcium and magnesium.

Abrol and Bhumbla (1979) made an effort to simplify the determination of gypsum requirement of alkali soils from knowledge of soil pH in order to provide fast and accurate advisory service. They suggested that gypsum requirement for three different types of soils based on pH of 1:2 soil: water suspension.

Abrol *et al.* (1980) gave the ratings for alkali problem based on pH and ESP. The alkali problem is very low when the pH of 1:2 soil: water extract is below 8.6 and is rated extremely high when pH exceeds 9.8

Gupta *et al.* (1989) described relationship between pH and exchangeable sodium in calcareous soils containing sodium carbonate. The ESR (Exchangeable Sodium Ratio) and pH are quantitatively related and the relationship governing their dependence can be derived from basic considerations of Na - (Ca+Mg) exchange. Therefore the relationship could be used to determine ESP of the soil.

Hebsur *et al.* (1990) studied the effect of ESP and electrolyte concentration on dispersion of some black and red soils of North Karnataka. The results revealed that dispersion index increased with increasing ESP and decreasing electrolyte concentration. At lower ESP the dispersion was rather unaffected in black soils, while in red soils the dispersion was substantial.

A study was conducted by Patagundi *et al.* (1996) to characterize and classify the salt affected Vertisols occurring in Tungabhadra left bank command area in Karnataka. The pH of the soils varied from 7.6-8.6. Organic carbon content was very low and free lime varied from 6.5-16.5 per cent. Further the ESP values varied from 8.5-31.0 per cent and sodicity increased with depth.

Katigenavar (1998) studied 12 soil profiles of Ghataprabha and Malaprabha irrigation projects in Karnataka. The soils investigated have been deteriorated on account of high exchangeable sodium as revealed by chemical properties. Sodicity was the major problem prevailing in these soils. Regarding nutrient status, the soils were low in nitrogen while phosphorus and potassium were low to medium.

Srinivasa (1995) characterized sodic soil in six profiles of the irrigated areas of Vishweshawaraiah canal tract of cauvery command area. All the soils were alkaline in reaction (8.4-10.1) and electrical conductivity ranged from 0.28-1.5 dS m^{-1}. The ionic composition with respect to water soluble ions indicated that sodium was the dominant cation in all the soil bodies. The profiles were $Na^{+}>Ca^{2+}>Mg^{2+}>K^{+}$ cationic type and $HCO_3^{-}>Cl^{-}>SO_4^{2-}>CO_3^{2-}$ anionic type. Exchangeable sodium percentage in all the profiles were sodic in nature with >15 per cent.

Lakshminarayanamurthy (2003) characterized eight soil profiles occurring in three command areas namely, Cauvery command area, Vanivilas command area and Bhadra command area. Soils were sandy clay loam to clay in texture; structure ranged from granular to massive, drainage was very poor. The pH values ranged from 8.6-10.6. The dominant cation in the soil solution and exchange complex was sodium. The exchange complex of these salt affected soils revealed high CEC which is dominated by sodium saturation resulting in high ESP.

Sharma *et al*. (2005) characterized and classified the salt affected soils of Bhilwara district of Rajasthan. Soils were moderately shallow to very deep, sandy loam to clay loam in texture and calcareousness increased with depth. Soils were alkaline having ECe values higher in surface. Among the soluble ions Na^{+} and Cl^{-} dominated and were followed by Ca^{2+} and HCO_3^{-} in the extract.

Guruprasad (2005) characterized the nature of soils under Kabini tract of Cauvery command area. Soils were sandy clay loam to clayey in texture, pH ranged from 8.60-9.05, soluble salt content ranged from 0.41-1.39 dS m^{-1}. The ionic composition was in the order of Na>Ca>Mg>K, SAR 3.9-19.6, exchangeable sodium 1.4-15.0, CEC 14-40 c mol(p+) kg^{-1} of soil and exchangeable sodium percentage 9.39-40.8 per cent.

Chunchun kumar *et al.* (2006) studied the release of Ca+Mg, Na and HCO_3 in an alluvial alkali soil treated with four levels of calcium carbonate. The treated soil samples were incubated for 120 days at different moisture regimes and with two different levels of organic matter. The results indicated that the release of Ca+Mg increased due to dissolution of $CaCO_3$ with increasing levels of $CaCO_3$, moisture content and the effects were more pronounced in the presence of organic matter.

2.3 Reclamation of sodic soil using different amendments

Basically, reclamation or improvement of sodic soils requires the removal of part or most of the exchangeable sodium and its replacement by the more favorable calcium ions in the root zone. This can be accomplished in many ways, the best dictated by local conditions, available resources and the kind of crops to be grown on the reclaimed soils. Soil amendments are materials, such as gypsum or calcium chloride, that directly supply soluble calcium for the replacement of exchangeable sodium, or other substances, such as sulphuric acid and sulphur, that indirectly through chemical or biological action, make the relatively insoluble calcium carbonate commonly found in sodic soils, available for replacement of sodium. Organic matter decomposition and plant root action also help in dissolving the calcium compounds found in most soils, thus promoting reclamation but this is relatively a slow process. The kind and quantity of a chemical amendment to be used for replacement of exchangeable sodium in the soils depend on the soil characteristics including the extent of soil deterioration, desired level of soil improvement crops intended to be grown and economic considerations.

Patel *et al.* (1990) reported that gypsum was found superior in reducing the exchangeable sodium percentage than pyrites for few alkali soils of Ludhiana (Punjab). Similarly patel and Bhajan Singh (1991) opined that gypsum treatment significantly reduced the pH and ESP and increased the exchangeable Ca and Mg contents of soil at all levels of application than pressmud and pyrites.

Koo *et al.* (1990) conducted a study to compare rinsing and leaching techniques for two coarse textured and one fine textured soil with three levels of gypsum treatment (0, 4.5 and 9.0 t ha^{-1}). Treatments of 4.5 and 9.0 t ha^{-1} gypsum were more efficient than treatments without gypsum. Leaching followed by 4.5 t ha^{-1} of gypsum treatment is effective in reclaiming sodic soils, provided drainage through the soil is adequate. The rinsing method with 4.5 t ha^{-1} of gypsum treatment has potential as a reclamation method, when drainage through the soil is poor.

Patel and Singh (1991) studied the effects of application of gypsum, pressmud and pyrites on soil properties under percolated and unpercolated conditions. Gypsum treatments were more effective in removing sodium in leachate whereas, cumulative removal of carbonates and bicarbonates was highest with pressmud treatment. Gypsum was more effective in reducing the pH, ESP and increased the exchangeable calcium and magnesium content of soil. The highest yield of rice was recorded with pressmud followed by gypsum and pyrites.

Anand Swarup (1991) studied the effects of gypsum with green manure and farm yard manure on nutrition of rice in a sodic soil with pH 10.2. Application of gypsum markedly decreased the pH to 9.2 after three months, while combination of gypsum with green manure and farm yard manure reduced it to 9.0 and ESP reduced from 86 to 28 percentage. Rice responded significantly to zinc in combination with gypsum.

Chauhan (1995) observed that pH decreased from 10.5-8.6 with the application of gypsum @ 50per cent GR+ 15tonnes of pressmud per hectare for alkali soils of Faizabadh in Uttar Pradesh. And also application of gypsum and pressmud increased the uptake of N, P, K and Zn by rice crop in sodic soil.

Najar and gupta (1996) reported that gypsum application decreased pH, EC, Exchangeable Na, ESP,CO_3 and HCO_3 contents and increased the organic matter content, exchangeable Ca^{2+}, K^+ contents of sodic soil.

Ilyas *et al.* (1997) reported that in a field experiment conducted at Jodhpur (Rajasthan) on alkali soils, treatments receiving crop rotation with gypsum application significantly decreased the pH, EC, SAR and chlorides in the top 20 cm soil.

Bachan Singh *et al.* (1999) studied the comparative effects of gypsum, pyrites and sulphitation cane filtercake on soil properties in alkali soils of Karnal(Haryana). The results revealed that there was a significant reduction in pH due to addition of sulphitation cane filter cake followed by gypsum and pyrites. But, gypsum and pyrites decreased soil salinity whereas application of sulphitation cane filtercake resulted in increase in EC of the soil.

Solaimalai *et al.* (2001) reported that application of pressmud improved the soil fertility, nutrient uptake and yield in sodic soil. Application of gypsum in combination with pressmud resulted in better pH reduction than pressmud alone.

Chun *et al.* (2001) conducted a study with use of by-product from flue gas desulfurization (FGD) to reclaim sodic soils by controlling the pH and excessive Na^+. The results revealed that pH, exchangeable sodium percentage (ESP), clay dispersion and soluble Na^+ in the soil decreased and soluble Mg^{2+} and soluble K^+ in the soil increased. The soil pH was reduced from 9.0 to 7.7 by applying the by-product. However, the by-product decreased the concentrations of total N and P in corn leaves in this study.

Rathod *et al.* (2003) reported that efficiency of gypsum in reclaiming sodic Vertisol when used in association with FYM followed by irrigation with alkali water. They concluded that integration of gypsum and FYM with NPK reduced deleterious effect of alkaline water applied to sodic Vertisols and there was decrease in sodicity of soil.

Hargopal Singh and Bajwa (2003) studied the effect of gypsum and sodic irrigation on the precipitation of Ca and removal of Na from a sodic soil reclaimed with different levels of gypsum (33, 67 and 100 per cent) of the total gypsum requirement of the soil) and growth of rice was investigated in a greenhouse experiment. Precipitation of Ca and carbonates and soil Na saturation increased with increase in sodicity of irrigation water. Application of gypsum for initial sodic soil reclamation or at each irrigation (G_{ei}) during growth of rice and wheat increased the removal of Na from the soil and decreased exchangeable sodium percentage (ESP) and pH.

A column leaching experiment using sodic water was conducted on a sodic, non-saline soil dominated by smectitic clays. Soil was amended with gypsum and langbeinite at rates equivalent to exchangeable Na at soil depths of 0.15 and 0.30 m. Significantly less exchangeable Na and lower SAR of the soil water was found in the lower sections of the soil columns, and K_{sat} was greater for the amended treatments than for the control. High solubility of the langbeinite resulted in the highest K_{sat} value, with possible increase in electrolyte concentration and reduction of clay swelling and dispersion in the first 12 hours. However, there was no significant difference in reclamation efficiency between equivalent rates of two amendments throughout the experiment (Aydemir and Najjar, 2005)

Munir Zia *et al*. (2006) carried out field experiment to compare the effectiveness of SAG (sulfurous acid generator) and alternate amendments applied on an equivalent basis to grow rice crop. SAG treatment of saline-sodic tube well water decreased only residual sodium carbonate (RSC) from 5.4 to 3.6 $mmol_c\ l^{-1}$, and had no beneficial effect on its sodium adsorption ratio (SAR) or electrical conductivity (EC). All the treatments kept soil EC and SAR around their respective threshold levels. For paddy yield, SAG, sulfuric acid, and gypsum treatments depicted non significant differences. SAG and sulfuric acid treatments of water were about six times expensive than that of gypsum. It was concluded that soil-applied gypsum, to counter sodic hazards of irrigation water, is economical to sustain irrigated rice in dry regions.

Chun *et al.* (2007) conducted a column experiment using organic matter (rice straw) and chemical amendments (H_2SO_4, $CaSO_4$, and $FeSO_4$), to evaluate the physical and chemical properties of the soil influenced by the changes in HC, penetrability of soil surface, pH, electrical conductivity, CO_3^{2-}, HCO_3^-, Ca^{2+}, Na^+, sodium adsorption rate (SAR). Among the chemical amendments, H_2SO_4 and $FeSO_4$ were more effective than $CaSO_4$ to restore HC, electrical conductivity, Na^+, and SAR. Organic matter decreased the concentrations of CO_3^{2-}, HCO_3^-, and Na^+ in soil solution and increased the total volume of the leachate.

A field experiment was conducted by Joachimh *et al.* (2007) to study the effectiveness of supplying gypsum ($CaSO_4.2H_2O$) or farmyard manure (FYM) alone or both mixtures on the reclamation of a sodic soil. Results also showed that combining FYM with gypsum significantly (p_0.05) improved pH, electrical conductivity of the saturated paste (ECe), exchangeable sodium percentage (ESP), infiltration rate (IR), osmotic potential (OP) and available water capacity (AWC) of sodic soils. The FYM was the second-best treatment in the improvement of pH, ESP and EC whereas gypsum was second in the improvement of ESP, IR and maize yield.

Diamantis *et al.* (2008) conducted soil column experiments & showed that a surficial sodic soil is efficiently reclaimed using freshwater, after the addition of saturated gypsum solution. Gypsum application in the field was beneficial in terms of maintaining high soil permeability, increased water infiltration and neutral pH after a rainfall event. Two different reclamation techniques for the plough layer of a sandy loam sodic soil were tested in laboratory columns, 25 cm long and 10 cm in diameter; the first using freshwater alone and the second using a saturated gypsum solution. The dynamics of salt removal were studied by continuous analysis of the water drained from the bottom of the columns. When freshwater was used, sodium presented the lower removal rate and adversely affected soil permeability. When gypsum solution was used, calcium was present in the flushing solution and the effect of sodium dominance on clay dispersion and soil clogging was limited.

2.4 Raw spentwash as an amendment for reclamation of sodic soil

Singh (1961) reported that raw spentwash because of its nature resulted in a marginal decrease in soil pH, although values regarding total N, available P and K contents of the soil were found higher in spentwash treated plots than in control.

Pawar (1984) reported that application of spentwash followed by irrigation rather than its dilution at the time of application was very effective in reclaiming sodic soil by reducing significantly exchangeable sodium content of an alkali soil of Rahuri (Maharashtra).

Guruswamy (1986) stated that discharge of untreated spentwash on land lowered the soil pH and wastewater produced in the distillery carried a high organic load that caused severe fouling of atmosphere.

Mbagwu and Ekwealor (1991) analyzed spentwash for its chemical characteristics. They reported that besides containing plant nutrients it also possess some of the growth promoters and acidic nature of raw spentwash can be exploited for reclamation of sodic soil.

Rachhpal Singh *et al.* (1980) reported that addition of raw spentwash without dilution is very effective in increasing the water intake rate of sodic calcareous soil in Ludhiana (Punjab).The pH and salt contents decreased to safe limits but the extent of decrease was less in lower depths. Exchangeable Sodium Percentage reduced from 100to 2 in the top 15 cm soil. Application of spentwash followed by irrigation rather than the dilution of spentwash at the time of application was very effective in reclamation of sodic soil.

Rajukannu *et al.* (1996) in alkali soils of Tamil Nadu reported that application of 5 lakh liters of raw spentwash was found to be optimum for the soil having pH range from 8.5-10.0. For soils having a pH less than 8.5 the untreated distillery spentwash should not be used. Hence, a dose of 5 lakh liters per hectare can be considered to be optimum.

The use of filter cake and stillage (Vinasse) as amendments for the reclamation of saline sodic soil were studied in green house experiment using an alluvial sandy loam from an irrigated site. The treatments consisted of combined application of gypsum and filter cake treatment whereas gypsum alone was better than filtercake alone. Leaching with stillage showed better results in comparison to rainwater in all the treatments including control, indicating the possibility of reclamation of saline sodic soils with stillage without the incorporation of conventional amendments (Ruiz *et al*., 1997).

Mohammed Haroon and Subash Chandra Bose (2004) reported that, untreated distillery spentwash at 0.15 million litres per hectare can be used as an amendment for the recalamation of non saline calcareous sodic soil in Tiruchirapalli (Tamil Nadu). It should be applied during summer and a time lag of 40 days should be allowed to overcome the depletion of oxygen. The distillery spentwash alone or in combination with gypsum is effective in spot reclamation of alkali soils.

In a study conducted on calcareous sodic soil of Madurai (Tamil Nadu) by Bhakiyathu Saliha *et al.* (2004) it was reported that application of raw spentwash at 1.25 lakh litres ha^{-1} helped in reducing the pH and ESP of the soil to transfer limits besides enhancing soil nutrient status. They found that higher contents of Ca, Mg and S in spentwash might have helped in reducing the sodicity by replacing Na from exchange complex they also found that integrated application of distillery spentwash (1.25 lakh liters ha^{-1}) with FYM @ 12.5 t ha^{-1} or bio compost at 3 t ha^{-1} is cost effective and eco friendly technology to reclaim and enhance the fertility status of sodic soil.

Sharmila rahale *et al.* (2007) found that the application of spentwash to sodic soil decreased the soil pH to a range from9-9.8 to 8.1-8.9.The EC of soil increased during the initial period upto 30 days and decreased thereafter. The initial ESP range of 30.0-33.0 was decreased to 21.6-25.9 per cent. A marginal increase in N, P & substantial build up of K in soil was noticed due to the application of spentwash.

Field experiments were conducted in the sodic soils of Mallasamudram soil series of Salem district in two locations having pH 9.5 & 10 respectively. In spentwash treated plot soil pH was significantly reduced from 9.42 - 8.25 in location one (L_1) and from 9.95-9.45 in L_2 compared to all other treatments and reduced the ESP from 44.0 to16.2 per cent in L_1 & 70.0 to 22.0 per cent in L_2 respectively. The application of spentwash significantly improved the rice crop growth & yield of rice (Balasubramanian *et al.*, 2007).

Geetha *et al.* (2007) revealed that on an average there was 20-25per cent increase in rice yield in reclaimed soil treated with spentwash when compared to non-reclaimed one.

Bakiyathu Saliha *et al.* (2007) studied the effect of one time application of raw spentwash @ $125m^3$ ha^{-1} for reclamation of sodic soils. The results revealed that the average pH of soil samples decreased from 9.10-8.35, EC increased to an average value of 1.52 dS m^{-1} and organic carbon content of soil was increased to 0.98per cent with the application of spent wash.

Susheel Kumar Sindhu *et al.* (2007) reported that the presence of Ca in considerable amounts makes the spentwash a potential amendment for reclaiming sodic soils. Large amounts of soluble salts have been found to be leached from calcareous and high pH sodic soils amended with spentwash. Application of spentwash has resulted in leaching of high amounts of sodium from high pH sodic soils reflecting its potential in ameliorating these soils.

2.5 Response of cereal crops to ferti-irrigation of spentwash

Irrigation with distillery wastewater seems to be an attractive agricultural practice which not only augments crop yield but also provides a plausible solution for the land disposal of the effluents. When the distillery effluents are used for irrigation in fallow lands, the microbes present in it transform the lands into fertile ones, giving high yields of crops. The utilization of distillery effluent for irrigation of land would make available nitrogen, potash, phosphorus and other nutrients. The added advantage of this application would be that these fertilizers would be available to soil in organic form. So it will be an attractive practice to utilize the distillery effluents for ferti-irrigation of land.

Pujar (1995) reported that application of diluted distillery effluent increased the up take of Zn, Cu, Fe and Mn in maize and wheat as compared to control and the highest total uptake of these were found at lower dilution levels than at higher dilution levels.

Patil and shinde (1995) indicated that acidic characteristics of spent wash resulted in evolution of CO_2, which was five times greater than with FYM, which inturn significantly affected the dry matter yield of maize.

Singh and Raj Bahadur (1997) found that maize crop tolerated effluent irrigation of five times dilution. This diluted effluent irrigation had positive effect on crop growth and soil productivity. Plants with five times diluted effluent irrigation plots were significantly taller and other growth parameters were also on higher side than higher dilution effluent irrigation plots. They concluded that effluent up to 1000 mg per liter BOD can be safely used for irrigating maize, which left a positive effect on soil fertility.

Singh and Raj Bahadur (1998) reported that twelve pre sowing irrigations with the distillery effluent had no adverse effect on the germination of maize but improved the growth and yield.

Ramanna *et al.* (2001) evaluated the response of maize to distillery effluent and found that there was an increase in dry matter production, growth parameters like CGR and RGR, chlorophyll content, yield and yield attributes as compared to control.

Arafat syed and Yassen Abde Elazim (2002) studied the fertilizing efficiency of vinasse in a pot experiment on sandy soils in green house. They found that the addition of vinasse within all tested rates (0.5 per cent, 1per cent and 2 per cent) resulted in significant increase in both grain and straw yield as compared to control. However, there was no significant difference in wheat yield between fertilizer and vinasse treatments. Vinasse applied in irrigation water (2per cent) caused highly significant increase in wheat grain yield .

In two years experiment conducted at Dharwad (Karnataka) in red soil it was found that highest wheat grain yield was recorded when it was irrigated with 1:50 diluted spentwash compared to lower dilutions. Whereas significantly lowest grain yield of 10.56 q ha^{-1} was recorded with undiliuted effluent (Sukanya and Meli, 2004).

Hati *et al.* (2004) found that irrigation of post methonated effluent at 5 cm depth to soyabean and 2.5 cm depth to wheat is optimum from yield, salinity and sustainability point of view.

Pandey *et al.* (2008) conducted a laboratory experiment to assess the waste water quality parameters of treated distillery effluent and the effect of various concentrations like 0 per cent, 25per cent, 50per cent, 75per cent & 100per cent on seeds germination, speed of germination, peak value and germination value of three selected seeds i.e. Wheat (*Triticum aestivum*), Pea (*Pisum sativm*) and Lady's Finger (*Abelmoschus esculentus*). Germination percentage decreases with increasing concentration of effluent in all the tested seeds, where as the germination speed, peak value and germination value increases from control to 25per cent and 50per cent concentration and decreases from 50per cent to 75per cent and 100per cent effluent.

2.5.1 Response of rice to distillery spentwash

Devarajan and Oblisamy (1995) reported that effluent irrigations significantly increased the soil pH, EC, OC and N, K, Ca, Mg, S and micronutrient content of soil. The 50 times diluted effluent irrigations recorded the higher rice grain and straw yield.

Pathak *et al*. (1998) reported that application of treated distillery effluent increased the rice grain and biomass yield. Application of effluent increased EC, OC and potassium status of post harvest rice soil and reduced the bulk density and increased the water content of soil.

Pathak *et al.* (1999) in a field study used diluted post methanation distillery effluent as a soil amendment and reported an increase in 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 content of the soils improved with effluent application.

Annadurai *et al.* (1999) conducted field experiment to study the effect of distillery effluent with different dilutions and organic amendments on rice productivity. The results revealed that effluent diluted 50 times with water along with neem leaves at 6.25 t ha^{-1} increased the rice yield without any detrimental effect on soil health. The treated effluent irrigations resulted in significant increase in soil pH, EC and organic carbon content.

Phanapavudhikul (2005) reported that diluted spentwash application to field has resulted in 2-3 fold increase in rice yield.

Anandkrishnan *et al.* (2007) reported that application of increasing doses of post methanated effluent significantly increased grain & straw yield of rice. An increased grain yield of 15.8per cent was recorded due to the application of PME at the rate of 1.5 lakh liter ha^{-1} over control.

Sharma *et al.* (2008) conducted a green house experiment to study the impact of premethanation (PREME) and postmethanation (POME) distillery effluent applied as pre-sowing irrigation (PSI) along with graded levels of inorganic fertilizers on the grain and straw yield and nutrient content of a rice crop (var. PR 116). Maximum grain yield (29.4 g pot^{-1}) was recorded with the application of 100per cent recommended NPK along with one pre-sowing irrigation (PSI) through POME and the lowest yield (7.4 g pot^{-1}) was obtained with 2 PSI applied through PREME without any inorganic fertilizers.

2.6 Effect of spentwash on soil properties

Being very rich in organic matter, the utilization of distillery effluents in agricultural fields creates organic fertilization in the soil which increases availability of certain nutrients and capability to retain water and also improves the physical structure of soil. Availability of nutrients plays an important role in increasing the yield and quality of crops. Though it is considered as wastewater, scientific use of this helps in providing valuable nutrients to crops by improving the nutrient status of soil and thus giving higher yields. Some of the reviews on these aspects are covered below:

2.6.1 Effect on soil physical properties

Mbagwu and Ekwealor (1991) studied that the progressive levels of distillery effluent from 2.5 to 10 per cent increased the mean weight diameter of water stable aggregates (1.62 mm to 2.20 mm), moisture retention (17.17per cent to 20.25per cent) and available water holding capacity of soil (14.7per cent to 18.3per cent).

Singh and Raj Bahadur (1997) stated that distillery effluent irrigation decreased the rate of infiltration and bulk density of soil, which are favorable traits for sandy soils. Whereas saturated hydraulic conductivity, bulk density and volumetric water content of soils improved with effluent application (Pathak *et al*., 1999).

Patil *et al*. (2000) reported that pH values of soil were decreased with increased levels of spentwash but EC values were increased with increased levels of spentwash. Depletion of calcium from soil had adverse effect on structure and hydraulic conductivity of soil.

Hati *et al.* (2005) noticed that the per cent water stable aggregates and water retention at field capacity were significantly high, while penetration resistance of the surface soil was significantly low in all the spentwash treated plots.

Chandra *et al.* (2005) conducted a study to evaluate the effect of distillery effluent on hydraulic conductivity of a sandy loam alluvial soil and compared the effect of inorganic salts of potassium (K) with that of distillery effluent on hydraulic conductivity of soil. Application of post methanated effluent (PME) and salts increased the hydraulic conductivity of soil by 3 to 4 fold as compared to that of the untreated soil. With the increasing levels of salt concentration, the rate of increase in hydraulic conductivity initially decreased, but at 100per cent salt level, soil hydraulic conductivity increased sharply. The oxidized PME, which contained only the inorganic salts present in the PME, had highest hydraulic conductivity at 100per cent salt level followed by PME and inorganic salts.

2.6.2 Effect on soil chemical properties

Orland *et al*. (1985) applied vinasse for 20 years and found that soil was benefited in terms of pH increase, higher potassium, calcium, magnesium and greater CEC.

Scandaliaris *et al.* (1987) pointed out that application of spentwash to soil increased the soil nitrate-N availability, EC and interchangeable potassium. Chang and Li (1989) found that application of vinasse to the main crop of cane increased the available K content of the surface soil and remained high even after the harvest of first ratoon.

Taluk and Medeiros (1989) also observed increased soil pH, available N, P, K, Ca and Mg by 80 m^3 vinasse application per hectare. Irrigation to cane field with distillery effluent affected the tendency for exchangeable calcium to increase. Sweeny and Graetz (1991) found that the addition of distillery effluent regardless of rate raised the soil pH owing to increase in soil K, Ca, Mg and Na contents. Further, they noticed that digested distillery effluent application increased soil concentrations of most elements.

Pawar *et al*. (1992) found that addition of spentwash decreased the pH and EC of soil. There were significant changes in exchangeable K, Ca and Mg. Further, the DTPA extractable Fe and Mn contents of soil were significantly increased at all stages of crop growth treated with diluted spentwash. Shinde *et al.* (1993) observed increased EC and available K in soil and saturation paste extract when applied with spentwash solids. Further, it increased the available N, P and DTPA extractable Fe, Mn and Zn in the soil at the harvest of sorghum.

Machaado-de-Armas *et al.* (1994) in sugar cane soils irrigated with distillery effluent found that pH was strongly and positively correlated with rates of distillery effluent application. Mg and Na were the main cations affecting soil pH. While, available P and exchangeable cations with the exception of Ca, were positively and organic matter was negatively correlated.

Zalawadia and Raman (1994) recorded higher values of electrical conductivity, organic carbon, available N, P and K with the usage of effluent water than with normal water at the same level of fertilizer application. There was build up of soil fertility with effluent application particularly soil organic carbon and potassium status (Singh and Raj

Bahadur, 1997). Further, with increase in the amount of effluent added, there was increase in pH, EC, available N, P and K.

Anil Kumar (1995) found that irrigation with diluted distillery wastewater along with gypsum and pressmud reduced the exchangeable sodium and increased the available nitrogen, phosphorus and potassium and exchangeable calcium and magnesium contents.

Joshi *et al*. (1996) exploited the manurial potential of post methanation effluent (PME) applied at different levels. They concluded that dilution to an extent of 1:10 was best and it supplied 120, 8, 2400 and 400 kg ha^{-1} of NPK and sulphates respectively. Effluent use at lower dilution levels will supply more of sulphates and it adversely affects the chemical properties of soil by increasing the EC and sulphate content in the soil.

Zalawadia *et al*. (1997) studied the effect of irrigation with tube well water (S_o) as well as with spentwash diluted 25 (S_{25}), 50 (S_{50}) and 100 (S_{100}) times on yield of and nutrient uptake by sugarcane grown on typic chromustert. The post harvest nutrient status of soil revealed that there was significant increase in soil organic carbon, available N, P, S, Fe, Mn, Cu & Ni over control. While the exchangeable Na, Ca and Mg significantly decreased with increase in proporion of spentwash in irrigation water, but Pb and Cd remained unaffected due to spentwash treatments.

Singh and Raj Bahadur (1998) found that the pH and electrical conductivity of the soil slightly increased. Whereas, the soil organic carbon, nitrogen, phosphorus and potassium contents were increased significantly with increase in the number of pre-sowing distillery effluent irrigation. Annadurai *et al*. (1999) revealed that, pH, EC and organic carbon increased with increase in concentration of the effluent (decrease in dilution).

Study by Pathak *et al*. (1999) revealed that there is a possibility of salinity development in the long run with higher level of effluent application. The treated distillery effluent irrigation resulted in significant increase in soil pH, EC and organic carbon content.

The field experiment on a reddish yellow latosol in tres pontas, Minasgerais, Brazil, with pineapple crop (*cv.* Smooth Cayenne) given with 0, 100, 200 and 400 m^3 vinasse per hectare as a K source. Vinasse increased K, Ca and Mg content of soil (Paula *et al.*, 1999).

Application of spentwash in case of Vertisol and Alfisoil marked an increase in SAR and ESP. However, these values (SAR< 3.62, ESP< 4.8) were well below the threshold levels, suggesting that even at higher rate, the spentwash application is unlikely to cause any sodicity problem in these soils (Murugaragavan, 2002)

Canellas *et al.* (2003) studied the chemical properties of soil under long term sugarcane crop with vinasse application and without slash burning. . Results indicated that application of crop residue on the soil surface and to a lesser extent the addition of vinasse increased the macro and micronutrients contents, organic carbon contents in the surface layer (0 – 20cm). The improvement of the chemical soil attributes favoured the formation of more polymerized alkaline soluble humic substances.

A field experiment was conducted during 2000 in red soil with wheat as test crop, employing different effluent dilution levels (1:5, 1:10, 1:25 and 1:50) in comparison with undiluted effluent and fresh water. Results indicated that available N, P, K, Zn, Cu and Mn contents in soil were decreased with increased dilution levels (Sukanya and Meli, 2003).

Hati *et al.* (2005) conducted field experiment for three years to evaluate the effect of spentwash on soil properties in deep black soil. The organic carbon and electrical conductivity of the surface soil increased significantly with application of spentwash, but the soil pH was not affected.

A field experiment was conducted to study the effect of ferti-irrigation of spentwash on sugarcane crop and on soil properties. It was found that chemical properties of soil did not differ significantly due to ferti-irrigation of distillery spentwash except organic carbon, available potassium and iron. Ferti-irrigation of distillery spentwash at

150per cent RDN recorded higher OC, available K and Fe after the harvest of crop (Suma 2006).

Madusudhana (2006) conducted field experiment in sandy clay loam soil to study the effect of spentwash on yield and quality of mulberry crop. Results revealed that soil pH, EC and organic carbon content were significantly increased due to the application of 1.5N through spentwash. Significantly higher available nitrogen, phosphorus and potassium contents were recorded in treatment which received 1.5 N through spentwash. Among the micronutrients DTPA-Fe, Mn, Cu content was significantly increased except DTPA-Zn content of soil.

2.6.3 Effect on soil enzymatic activities

When the distillery effluents are used for irrigation in fallow lands, the microbes present in it transform the lands into fertile ones, giving high yields of crops.

Goyal and Kapoor (1995) observed increased microbial biomass and dehydrogenase activity due to application of distillery effluent and concluded that a close relationship existed between the number of microorganisms and activity of enzymes in soil.

Kundu *et al.* (2001) observed increase in urease activity with the increasing level of distillery effluent in clay loam soil.

Murugaragavan (2002) noticed an initial enhancement in enzymes (phosphatase, dehydrogenase and urease) activities in soil amended with spentwash. But no marked difference was observed at the end of 60 days of incubation.

Urease activity of primary spentwash (PSW) was markedly inhibited as the volume of spentwash (SW) increased from 1 to 5 mL in assay medium. On contrary, PSW addition to the soil increased the urease activity (Kundu *et al*., 2001). Application of secondary treated spentwash as single dose prior to maize cultivation recorded higher amylase and catalase activity (Mallika *et al*., 2003).

Singh *et al.* (2004) conducted a pot experiment to study the effect of spentwash application on soil enzyme activity. Application of spentwash resulted in a significant increase in the activity of nitrate reductase and peroxidase. The activity of these enzymes increased with increase in dosage of spentwash. Further, the activity of dehydrogenase, acid and alkaline phophatase increased with increasing level of spentwash application.

Singh *et al.* (2005) studied the effect of raw and biomethanated spentwash on soil enzymatic activities. They found that the application of both the spentwash significantly increased the dehydrogenase and alkaline phosphatase activity more than the recommended NPK + FYM.

Bhakiyathu Saliha *et al.* (2005) conducted an incubation experiment to study the impact of spentwash on soil microbial and enzyme dynamics. Spentwash @ 55 ml/kg of soil recorded maximum number of bacteria, fungi and actinomycetes throughout the incubation period when compared to absolute control. The activities of urease and phosphatase were 21.8 g $kg^{-1}hr^{-1}$ and 134 g kg^{-1} hr^{-1} at 55 ml $kg^{-1}$of soil while control recorded minimum activity, the dehydrogenase activity increased with rate of spentwash application.

Suma (2006) reported that basal application of spentwash at recommended dose of nitrogen (RDN) significantly increased the dehydrogenase activity than spentwash application at 150 percent RDN. Application of distillery spentwash maintained higher urease activity and marginal decrease in acid phosphatase activity while alkaline phosphatase activity was on par with RDF+FYM.

Madhusudhana (2006) reported that application of distillery spentwash significantly increased the soil enzyme activities. Higher urease activity, dehydrogenase and alkaline phosphatase activity were recorded with 1.5N through distillery spentwash irrigation in 6 irrigations.

2.7 Effect of spentwash application on ground water quality.

Irregular and unscientific use of distillery effluent for irrigating crops without considering its impact on the environment pose problem of salinity and pollute the water.

Hence, an apprehension exists that the use of spentwash in agricultural fields may pose a serious threat to the groundwater quality due to high BOD and COD. Monitoring of groundwater pollutants in the effluent is of utmost importance to reduce the risk of pollution load beneath the effluent irrigation site, for maintaining water quality because of risk of leaching of organic and inorganic ions from effluent amendment.

Addition of spentwash on salinity build up in clay loam and silty clay soils and on the composition of soil leachates were studied by Somavanshi and Yadav (1990). According to them diluted spentwash will not add soluble salts to the soil provided there was sufficient leaching of soil solution. However, addition of concentrated spentwash would result in increased salinity of both soil and ground water.

Pollution of the Faren stream by six sugar factories, of which two distilleries discharged waste into a stream with no proper treatment thus making the water unfit for drinking, bathing or irrigation. Analytical results of samples and distillery effluents are significantly higher with respect to infiltration rate (29.6 and 29.2 cm/hr, respectively), as observed by Devarajan and Oblisamy(1995).

Impact of sugar mill and distillery effluents on water quality of River Gelabil, in Assam, during the operational period of the mill and also after its closure has been studied during the year 1990–91. Water samples from wells were collected fortnightly during November 1990 to April 1991 and monthly from May to October 1991 from various points on the course of the river. D_1 is the point where the mill discharges its untreated effluents into the stream and D_2 is another point on the course of the stream about 8 kilometers away. The effluent added high concentration of organic matter responsible for the deterioration of the river water quality with respect to pH, total suspended solids, dissolved oxygen, BOD and COD along with NH_4, NO_3 and PO_4. During the period when the mill remained opened, addition of organic matter was less and this was evidenced from the reduction in BOD and COD values (Baruah *et al*., 1993).

Orlando (1996) reported the use of vinasse and mineral N with regard to leaching of N from soil and possible pollution of ground water. NO, NO_3, NH_4 or other free N compounds were found in soil samples from depths of 0-2 m presumably because the N in the soil was fixed microbiologically. Joshi *et al*., (1994) noticed ground water contamination by effluent with high BOD and salt content near the lagoon sites in most of the distilleries.

Korndorfer and Anderson (1997) studied the use and impact of sugar alcohol residues vinasse and filter cake on sugarcane production in Brazil. Vinasse has been used primarily on ratoon cane and filter cake on plant cane. Increased sugarcane yield can be expected from the application of either vinasse or filter cake without detrimental effects on cane quality or environment. World wide, the interest in using sugarcane byproducts is growing, largely to decrease the production cost and environmental liabilities.

Pawar *et al*. (1998) analyzed water samples from 18 dug wells in the shallow basaltic aquifer and the results obtained showed spatial as well as temporal changes in the chemical properties of ground water. The temporal changes were attributed to climatic factors, whereas variations in the geo-chemical characteristics of ground water appeared related to pollution by effluents from the M/s Mula Sugar Factory (India) released into the stream flowing through the area.

Ramalho *et al.* (2001) analysed soil samples treated with sugarcane industrial residues (vinasse and filter cake) and their respective control areas at campus dos Goytacazes, Rio de Janeiro, Brazil for total contents of Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn in 1995. The results showed that the use of vinasse for more than 15 years in volumes of 300 m^3 ha^{-1} $year^{-1}$ did not increase the concentrations of the heavy metals in the Entisols and Inceptisols. The Inceptisols that received filter cake recorded increased concentration of all heavy metals with the exceptions of Zn and Mn. Even though the heavy metals concentrations were higher in this treatment the sequential extraction showed that these elements were present in nonlabile form in the soil.

Leaching experiment conducted by Malathi (2002) showed that large amounts of soluble cations were leached from soil amended with spentwash. Increase in the spentwash application had markedly enhanced the leaching of cations. Calcium was the dominant cation leached from calcareous Vertisol, whereas, greater amount of sodium was found leached from high pH sodic soil.

Anil Kumar *et al.* (2003) studied the effect of distillery spentwash on some soil characteristics and water. The effluent of Sir Sadilal distillery situated at Mansurpur, (Dist. Muzafarnagar) falls into the river Kali. Soil samples were collected very nearer to effluent channel and away from the channel. Comparison of the water and soil characteristics revealed that the effluent water (spentwash) is highly polluted with very high (far more than ISI standards) BOD, COD and dissolved /suspended solids contents which got diluted after mixing with the Kali water. Soil samples collected from effluent fed field showed higher sand content and organic matter compared to the soil without being fed with effluent.

Jain *et al.* (2005) conducted an experiment to assess the impact of long term irrigation with post methonated effluent on nitrates, sulphate, chloride, sodium, and potassium and magnesium contents in the ground water of two sites in North West India. Nitrate content in the ground water samples ranged from 16.95 mg L^{-1} in the unamended fields to 59.81 mg L^{-1} the effluent amended field during 2 years study. Concentration of TDS in water samples from tube well of the amended field was higher by 40.4 per cent over the tube well water of the unamended field.

Suma (2006) reported that leachate collected in piezometers after 60 days after spentwash application resulted in increased leaching of NO_3^-, HCO_3^-, Cl^-, and Na^+ with increasing depth while calcium and Mg^{2+} decreased with depth. Chemical Oxygen demand of percolating water decreased with increasing depth of soil column.

Though extensive work has been done on various aspects of spent wash utilization in agriculture, no research has been conducted on utilization of raw spent wash for reclamation of sodic and calcareous soils. Also no work has been done on utilization of primary treated spent wash as a fertilizer supplement for paddy and also on fertigation studies in paddy. Hence this work was taken up.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The present investigation involved (a) characterization of distillery spentwash (b) assessing the extent of reclamation of sodic soil using spentwash and growth and yield of paddy crop in reclaimed soil (c) ferti-irrigation studies in paddy. The details of the materials used and methodologies adopted are described in this chapter.

3.1 Characterization of distillery spentwash

Representative raw and primary treated spentwash samples were collected from M/s Chamundeshwari Distilleries Private Limited, Maddur Taluk, Mandya district at three months interval during August 2007 to August 2008. The samples were analyzed for pH, electrical conductivity, BOD, COD, total solids, total suspended solids, total dissolved solids, total nitrogen, phosphorus, potassium, sodium, calcium, magnesium, chlorides, sulphates and micronutrients (Zn, Cu, Fe & Mn) content by following standard procedures as given in Table 3.1 and the average values were presented.

3.2 Studies on utilization of distillery spentwash for reclamation of sodic soils

3.2.1 Green house experiment I: Effect of raw spentwash on reclamation of sodic and calcareous sodic soil under greenhouse condition

3.2.1.1 Experimental Details

To study the effect of raw distillery spentwash and gypsum application on extent of reclamation of sodic and calcareous sodic soils and to fix the dosage for field experiment, a green house experiment was conducted with two soils (viz. sodic and calcareous sodic) having pH >8.5 and (ESP) (>15). Different quantities of raw spentwash (RSW) was applied in to pots containing soils on the basis of gypsum requirement of the soils.

For this study bulk quantity of sodic soil sample was collected from VC, Farm, Mandya and that of calcareous sodic soil was collected from farmer's field at Hadly village, Maddur Taluk, Mandya District. Both the soils were analyzed for mechanical composition pH, EC, ESP and Organic Carbon content while the calcareous sodic soil

Table 3.1 : Methods followed for the analysis of distillery spentwash and leachate

Parameters	Methods	References
pH	Potentiometric method	Manivasakam, 1987
EC (dS m^{-1})	Conductometric method	Manivasakam, 1987
Total, dissolved and suspended solids (%)	Gravimetric method	Manivasakam, 1987
COD (mg L^{-1})	Potassium dichromate method	APHA, 1975
Carbonates (meq L^{-1})	Titration method using phenolphthalein indicator	Manivasakam, 1987
Bicarbonates (meq L^{-1})	Titration method using methyl orange indicator	Manivasakam, 1987
Total phosphorus (%)	Chloromolybdic acid blue colour method	Manivasakam, 1987
Total potassium (%)	Flame photometry	Manivasakam, 1987
Calcium (meq L^{-1})	Versenate titration method	Manivasakam, 1987
Magnesium (meq $L^{-1)}$	Versenate titration method	Manivasakam, 1987
Sulphur (mg L^{-1})	Turbidimetry	Manivasakam, 1987
Sodium (mg L^{-1})	Flame photometry	Manivasakam, 1987
Chlorides (mg L^{-1})	Winkler's method using potassium chromate as indicator	Manivasakam, 1987
Fe, Mn, Zn and Cu (mg L^{-1})	Atomic absorption spectrophotometry	Manivasakam, 1987

was analysed for the lime content also by following the standard procedures. The sodic soil was having a pH of 10.4 and ESP of 37.94 (per cent). The sodic soil was sandy clay loam in texture with electrical conductivity of 1.2 dS m^{-1} and the organic carbon content of 0.44 (per cent). The calcareous sodic soil was light black in colour with an alkaline reaction (pH 9.5). The lime content was 8.5 per cent and the ESP was 28.65 per cent. The electrical conductivity and organic carbon contents were 0.8 dS m^{-1} and 0.36 per cent respectively. Hence, these two soils were selected to assess the extent of reclamation by using raw spentwash. The gypsum requirement of these two soils was estimated and based on G.R. values, the following treatments were fixed.

3.2.1.1.1 Treatments:

T_1: Gypsum @ 50% GR

T_2: Gypsum @ 75% GR

T_3: Gypsum @ 100% GR

T_4: Raw Spentwash @ 2.5 lakh liters ha^{-1}

T_5: Raw Spentwash @ 5.0 lakh liters ha^{-1}

T_6: Raw Spentwash @ 7.5 lakh liters ha^{-1}

T_7: Raw Spentwash @ 10.0 lakh liters ha^{-1}

3.2.1.1.2 Replication: 3

3.2.1.1.3 Design: Completely Randomized Design

3.2.1.1.4 Methodology

The plastic pots (12 kg capacity) were cleaned and holes were made in the lower side of pots. Plastic tubes of diameter 1cm and about 30 cm length was taken and holes were made and on one side of the tube and then the tube was covered with nylon cloth and placed in such a way that the holes were facing up in the pots (plates 1& 2). The tube was inserted into the hole. The sides of the holes were plastered with cement. Gravel was spread over the plastic tube to prevent entry of the soil particles into the tube and to collect clear leachate sample (Plate1 & 2). The pots were filled with 10 kg of processed and sieved sodic and calcareous sodic soil. Calculated quantities of gypsum/raw spent

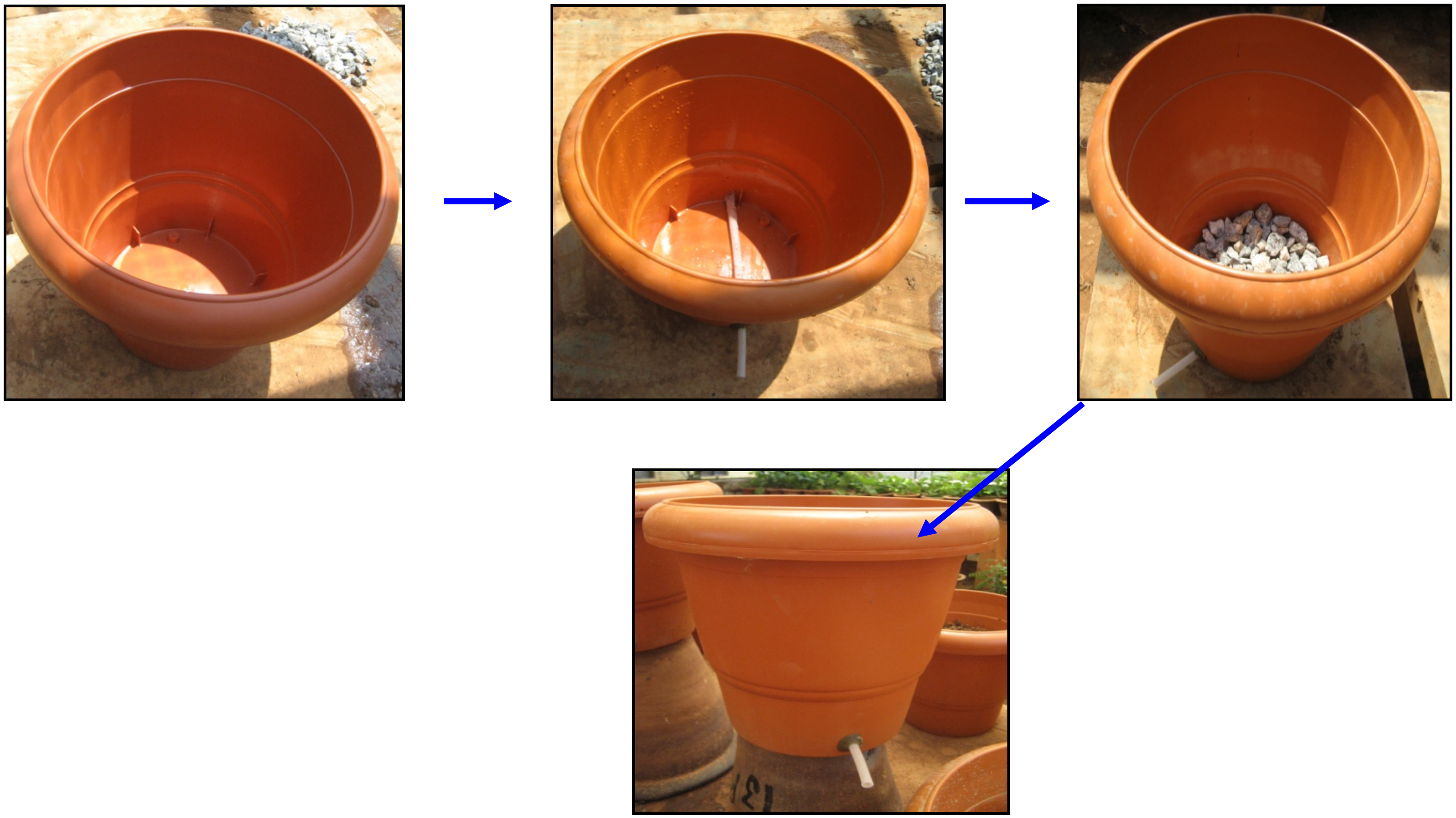

Plate 1 : Preparation of pots for reclamation studies

Plate 2 : Experimental set up for reclamation studies and leachate collection

wash were applied to pots containing sodic/calcareous sodic soil as per the treatments. After 30 days of spentwash application, pots were leached with good quality water 3-4 times to leach out and sodium salts and two seedlings (30 days old) of rice variety IR-30864 were transplanted in the pot. Regular plant protection measures were taken up besides maintaining the submergence level with water throughout the crop period.

The leachate and soil samples were collected at 30, 60, 90 and 120 days the soil sample were analyzed for pH, EC, Exch. Na, Ca Mg and ESP by following standard procedures (Table 3.2). The ESP of the soil was calculated using the formula (ESP = (Exchangeable sodium / Cation exchange capacity of soil) X 100). The leachate samples were analyzed for pH, EC, Exch. Na, Ca, Mg, Na, Cl^- ,CO_3^{2-} and HCO_3^- by following standard procedure and changes noticed with respect to pH and ESP the treatments were selected and further used for field experimentation at VC Farm, Mandya during Kharif 2008.

3.2.2 Field Experiment I- Reclamation of sodic soil using raw distillery spentwash

Based on the results obtained from the green house experiment-I, a field experiment was conducted on sodic soil plot at VC Farm, Mandya during Kharif 2008.

Before initiation of the experiment, a composite soil sample was collected from the experimental site at 0-15 cm depth. The soil sample was air dried, powdered and sieved through 2 mm sieve and analyzed for physico-chemical properties following standard procedure as given in Table 3.2.

The soil was sandy clay loam in texture alkaline in reaction with EC of 0.86 dS m^{-1} and ESP of 37.36 per cent.

3.2.2.1 Experimental Details

3.2.2.1.1 Design and Layout

The field experiment was laid out in randomized complete block design with five treatments and replicated four times. The plan of layout is given in Figure 3.1.

Table 3.2 : Methods followed for the analysis of soil and plant samples

Parameters	Methods	References
Soil Analysis		
pH (1:2.5)	Potentiometric method	Jackson, 1973
EC (dS m^{-1})	Conductometric method	Jackson, 1973
Organic Carbon (%)	Wet oxidation method	Walkey and Black, 1934
Cation Exchange Capacity (c mol (p+) kg^{-1} of soil)	Sodium acetate leaching method	Jackson, 1973
Avail. N (kg ha^{-1})	Alkaline potassium permanganate method	Subbiah and Asija, 1956
Avail. P_2O_5 (kg ha^{-1})	Olsen's extractant method, Colorimetry	Jackson, 1973
Avail. K_2O (kg ha^{-1})	N NH_4OAC extractant method, Flame photometry	Jackson, 1973
Exch. Ca [c mol (p^+) kg^{-1}]	N NH_4OAC extractant method, Versenate titration method	Jackson, 1973
Exch. Mg [c mol (p^+) kg^{-1}]	Versenate titration method	Jackson, 1973
Exch. Na [c mol (p^+) kg^{-1}]	N NH_4OAC extractant method, Flame photometry	Jackson, 1973
Avail. S (kg ha^{-1})	$CaCl_2$ extractant method, Turbidimetry	Black, 1965
DTPA extractable Fe, Mn, Zn and Cu (mg kg^{-1})	Atomic absorption spectrophotometry	Lindsay and Norvell, 1978
Plant analysis		
Nitrogen (%)	Kjeldahl digestion distillation method	Piper, 1966
Phosphorus (%)	Diacid digestion and vamadomolybdate method	Piper, 1966
Potassium (%)	Diacid digestion and Flame Photometer method	Piper, 1966
Calcium (%)	Diacid digestion and Versenate titration	Jackson, 1973
Magnesium (%)	Diacid digestion and Versenate titration	Jackson, 1973
Sulphur (%)	Diacid digestion and Turbidometry	Jackson, 1973
Fe, Mn, Zn and Cu (mg kg^{-1})	Diacid digestion and Atomic Absorption Spectrophotometer method	Lindsay and Norvell, 1978

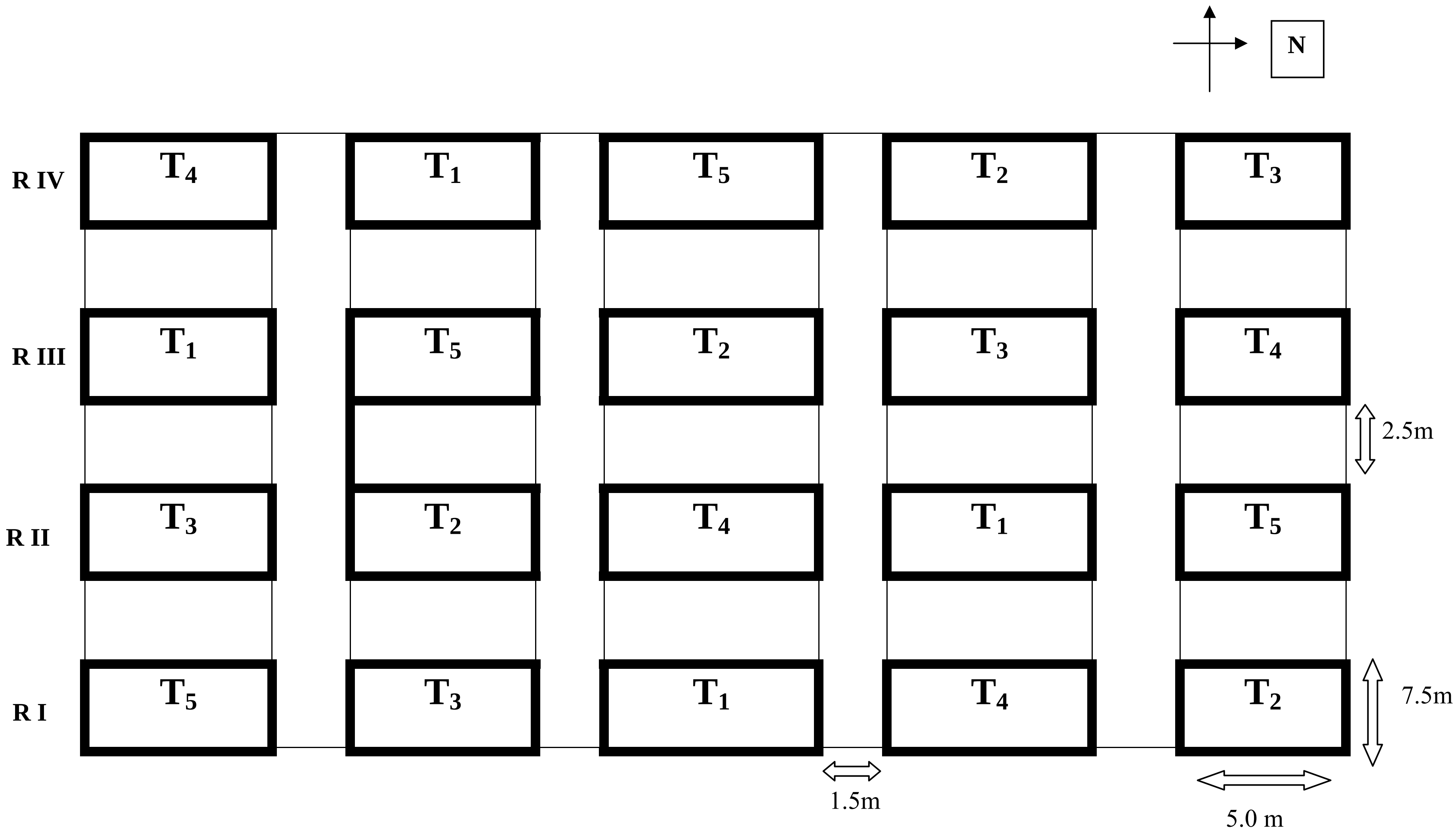

Fig. 3.1 : Plan of layout of filed experiment-I

3.2.2.1.2 Treatments

T_1: Rec.dose NPK (Control)

T_2: Gypsum @ 100% GR+Rec.NPK

T_3: Raw spentwash @ 2.5 lakh liters ha^{-1}

T_4: Raw spentwash @ 5.0 lakh liters ha^{-1}

T_5: Raw spentwash @ 7.5 lakh liters ha^{-1}

3.2.2.1.3 Plot size

Gross plot: 7.5m X 5.0m =35.5 m^2

Spacing: 20 X 10 cm

3.2.2.1.4 Crop and Variety: Paddy (IR-30864) was used as test crop.

This is a high yielding and saline tolerant variety, recommended for saline soils in Karnataka.

3.2.2.2 Imposition of treatments

The land was ploughed with tractor drawn mould board plough followed by harrowing and leveling. Layout was made according to the experimental design and plot size for planting paddy. Calculated quantity of gypsum and raw spentwash were applied to the plots one month before planting as per the treatment details. Plots were leached with the good quality water by providing proper drainage to leach out excess salts. After one month of raw spentwash application paddy seedlings were transplanted. Regular weeding and plant protection measures were taken to get a good crop.

3.2.2.3 Harvest

The crop was harvested during third week of December 2008. The crop was harvested to the ground level, harvested, bundled and stocked plot wise before recording the yield per plot.

3.2.3 Observations

3.2.3.1 Growth, yield and yield parameters

The bio metric observations like plant height at 30, 60, 90 days after planting and at harvest and yield parameters viz., number of tillers, number of panicles, panicle length, number of seeds per panicle, were recorded plot wise. The grain and straw yield were recorded and expressed in kilograms per hectare.

3.2.4 Collection of samples

3.2.4.1 Soil sampling

The representative soil samples were collected at 0-15 cm depth from each plot at different crop growth stages *viz.,* at tillering, flowering stage and after harvest of crop from 0-15 cm depth. Soil samples were shade dried, powdered and analyzed for different parameters following standard procedures as described in Table 3.2

3.2.4.2 Plant sampling

The grain and straw samples of each treatment were drawn at harvest and were analyzed for nutrient concentration and then the uptake of nutrients was calculated.

The grain & straw samples were analyzed for total N, P, K, Ca, Mg, S, Fe, Zn, Mn and Cu content following standard procedures (Table.3.2).

3.2.4.3 Piezometer studies

With a view to study the effect of application of different quantities of raw spentwash on the possibility of ground water pollution, piezometers were installed at 0.5 meter depth in plots of one replication.

3.2.4.3.1 Preparation of piezometers

The PVC pipes of 90cm length and 11 cm diameter were taken for the preparation of piezometers. The 90 cm PVC pipes were used to collect the percolating water from 0-0.5 m depth soil. The bottom 20 cm of PVC pipe was left undrilled to facilitate collection of leachate only. The top 20 cm was also left undrilled to prevent entry of stagnant water into the piezometer. For the middle part of the pipe (50 cm), perforations measuring 6 mm diameter were made using driller all around the pipe. The holes were covered using muslin cloth and 2 mm mesh to avoid the entry of soil particles into piezometer. Both the ends were covered using end caps. In each plot piezometers were placed in drilled holes and compacted tightly with soil (Plate 3).

3.2.4.3.2 Collection and analysis of leachate

From each treatment plot, leachate accumulated in the piezometer was collected after 30, 60 and 90 days of effluent application by "*draw and well*" method using rubber tube by sucking and the leachate was analyzed for pH, EC, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, CO_3^{2-}, HCO_3^{-}, Cl^{-}, SO_4^{2-} by using standard procedures as given in the Table 3.1.

3.3 Ferti-irrigation studies in paddy

3.3.1 Green house experiment II: Effect of ferti-irrigation of spentwash on growth and yield of paddy

To study the effect of primary treated spentwash for ferti-irrigation studies in paddy a pot experiment was conducted using soil from GKVK. Ten kilogram of soil was taken in plastic pot and calculated quantity of primary spentwash and urea were applied as per the treatment based on nitrogen requirement of the crop. Twenty days old paddy seedlings were transplanted in to the pots subsequently primary spentwash was applied as per the treatment to meet the nitrogen requirement of crop.

3.3.1.1 Treatments: 15

3.3.1.2 Treatment details:

T_1: RDF (NPK) +FYM

T_2: 100% RDN through DSW (in 6 irrigations) +balance of P through fertilizer

T_3: 150% RDN through DSW (in 6 irrigations) +balance of P through fertilizer

T_4: 100%RDN through urea (20% in each irrigation) + RDP &RDK through fertilizers

T_5: 100%RDN through urea (33.3% in each irrigation) + RDP &RDK through fertilizers

T_1: No amendment

T_2: Gypsum @ 100% GR

T_3: RSW @ 2.5 lakh liters ha^{-1}

T_4: RSW @ 5.0 lakh liters ha^{-1}

T_5: RSW @ 7.5 lakh liters ha^{-1}

Plate 3 : Piezometers installed in paddy field with different treatments

T_6: 100%RDN through urea (50% in each irrigation) + RDP&RDK through fertilizers

T7: 150%RDN through urea (20% in each irrigation) + RDP &RDK through fertilizers

T_8: 150%RDN through urea (33.3% in each irrigation) + RDP &RDK through fertilizers

T_9: 150%RDN through urea (50% in each irrigation) + RDP&RDK through fertilizers

T_{10}: 100%RDN through DSW (20% in each irrigation) + balance of P through fertilizer

T_{11}: 100%RDN through DSW (33.3% in each irrigation) + balance of P through fertilizer

T_{12}: 100%RDN through DSW (50% in each irrigation) + balance of P through fertilizer

T_{13}: 150%RDN through DSW (20% in each irrigation) + balance of P through fertilizer

T_{14}: 150%RDN through DSW (33.3% in each irrigation) + balance of P through fertilizer

T_{15}: 150%RDN through DSW (50% in each irrigation) + balance of P through fertilizer

RDN- Recommended Dose of Nitrogen

RDP- Recommended Dose of Phosphorus

RDK- Recommended Dose of Potassium

3.3.1.3 Replication: 3

3.3.1.4 Design: CRD

3.3.1.5 Variety: Thanu

3.3.1.6 Quantity of spentwash applied to supplement the nutrient requirement of paddy crop

The Recommended dose of Fertilizer for paddy under southern dry zone of Karnataka is 100:50:50 kg N: P_2O_5: K_2O ha^{-1}. The spentwash applied in this experiment was based on its nitrogen content (0.1%).

3.3.1.7 Quantity of spentwash applied to supplement nitrogen

The total quantity of spentwash required per hectare to meet the recommended dose of nitrogen (100 kg/ha) to paddy crop was calculated using formula,

$$\frac{100 \text{ X } 100}{\text{Percent total nitrogen in spentwash (0.1)}} = 100 \text{ m}^3 \text{ ha}^{-1}$$

The total quantity of spentwash required per hectare to satisfy the 150 % recommended dose of nitrogen (375 kg/ha) to paddy crop,

$$\frac{150 \times 100}{\text{Percent total nitrogen in spentwash (0.1)}} = 150 \ m^3 \, ha^{-1}$$

For treatments receiving only spentwash, the total quantity of spentwash required to supplement the 100% or 150 % RDN was calculated and applied in different splits as per the treatment details along with irrigation water for the respective treatments.

3.3.1.8 Supplementing the phosphorus requirement

The amount of phosphorus supplied through the distillery spentwash by applying at the rate of 100 % or 150 % RDN was calculated using formula,

$$\text{Phosphorus supplied by spentwash (kg/ha)} = \frac{\text{\% phosphorus in spentwash} \times \text{Total quantity of spentwash to required satisfy 100\% or 150\% RDN}}{100}$$

Potassic fertilizer was not applied for the treatments receiving distillery spentwash, as the spentwash contains large quantity potassium (1.06 %) and application of spentwash as nitrogen source satisfies the full requirement of potassium to paddy crop.

3.3.1.9 Manures and Fertilizer application

For the treatments receiving recommended dose of fertilizer, the N, P and K was given through urea, single super phosphate and muriate of potash and application was done as per the treatment details. The FYM (10 t ha^{-1}) was applied at the time of planting to treatment one alone. The schedule of ferti-irrigation of spentwash and fertilizer application is presented in Table 3.3**.**

The bio metric observations like plant height, number of tillers, number of panicles, panicle length, number of seeds per panicle, were recorded. Treatment wise the grain and straw yield were recorded and expressed in grams per pot. The grain and straw

Table 3.3 : Schedule of ferti-irrigation of spentwash and fertilizer application-Greenhouse experiment-II

Treatments	Spentwash required (m^3ha^{-1})	SW req. (m^3ha^{-1}/split)	Urea required kg/ha	Urea (Top dress) kg/ha/split	SSP kg/ha	MOP kg/ha
T_1	-	-	217.39	108.7	312.5	83.3
T_2	100	16.7	-	-	125	-
T_3	150	25.0	-	-	31.25	-
T_4	-	-	217.39	43.5	312.5	83.3
T_5	-	-	217.39	72.5	312.5	83.3
T_6	-	-	217.39	108.7	312.5	83.3
T_7	-	-	326.09	65.2	312.5	83.3
T_8	-	-	326.09	108.7	312.5	83.3
T_9	-	-	326.09	163.04	312.5	83.3
T_{10}	100	20.0	-	-	125	-
T_{11}	100	33.3	-	-	125	--
T_{12}	100	50.0	-	-	125	-
T_{13}	150	30.0	-	-	31.25	-
T_{14}	150	50.0	-	-	31.25	-
T_{15}	150	75.0	-	-	31.25	-

Table 3.4 : Schedule of ferti-irrigation of spentwash and fertilizer application-Field experiment-II

Treatments	Spentwash required m^3/ha	Basal appln. of RSW	SW required. (m^3/ha/split)	Urea (Basal) kg/ha	Urea (Top dress) kg/ha	SSP kg/ha	MOP kg/ha
T_1	-	-	-	108.7	108.7	312.5	83.3
T_2	-	-	-	108.7	108.7	312.5	83.3
T_3	300	250	16.7	-	-	-	-
T_4	300	250	12.5	-	-	-	-
T_5	350	250	33.3	-	-	-	-
T_6	350	250	25.0	-	-	-	-
T_7	350	500	16.7	-	-	-	-
T_8	350	500	12.5	-	-	-	-
T_9	600	500	33.3	-	-	-	-
T_{10}	600	500	25.0	-	-	-	-
T_{11}	100	50	16.7	-	-	121.9	-
T_{12}	100	50	12.5	-	-	121.9	-
T_{13}	150	75	25.0	-	-	26.6	-
T_{14}	150	75	18.8	-	-	26.6	-

samples of each treatment were drawn and were analysed for total nutrients concentration and uptake was calculated.

3.3.2 Field Experiment II - Ferti-irrigation studies in soil reclaimed with Spentwash and its effect on growth and yield of paddy

Based on the results of the ferti-irrigation studies under green house conditions, another field experiment was conducted in sodic soil at VC Farm, Mandya, during Summer 2009 to study the extent of reclamation achieved due to basal application of raw spentwash and to study the effect of primary spentwash used for ferti-irrigation on extent of reclamation incidentally achieved due to spentwash application in comparison with gypsum and also on growth and yield of paddy.

3.3.2.1 Soil of experimental site

Before initiation of the experiment, a composite soil sample was collected from the experimental site at 0-15 cm depth. The soil sample was air dried, powdered, passed through 2 mm sieve and analyzed for physico-chemical properties by following standard procedures as given in Table 3.2.

The soil was sandy clay loam in texture, alkaline in reaction with pH 8.9 has electrical conductivity of 0.64 dS m^{-1} and exchangeable sodium percentage of 31.5 per cent (Table 3.5).

3.3.2.2 Design and Layout

The field experiment was laid out in randomized complete block design with fourteen treatments and three replications. The plan of layout of the experiment is given in Figure 3.2.

3.3.2.3 Treatments:

T_1: Gypsum @50% GR + Recommended NPK

T_2: Gypsum @100% GR + Recommended NPK

T_3: RSW @ 50% GR +50% RDN through TSW (3splits)

Table 3.5 : Initial properties of the field experimental site soil at VC farm Mandya.

Parameters	Field Experiment-I	Field Experiment-II
Sand (%)	52.0	53.6
Silt (%)	17.5	17.8
Clay (%)	30.5	28.6
Textural Class	Sandy Clay loam	Sandy Clay loam
CEC [c mol (p^+) kg^{-1}]	28.96	22.56
pH (1:2)	9.50	8.90
EC (dS m^{-1})	0.86	0.64
Organic Carbon (%)	0.36	0.44
Available N (kg ha^{-1})	186.20	218.58
Available P_2O_5 (kg ha^{-1})	12.42	16.49
Available K_2O (kg ha^{-1})	205.60	284.82
Exchangeable Ca [c mol (p+) kg^{-1}]	6.0	5.75
Exchangeable Mg [c mol (p+) kg^{-1}]	3.0	3.25
Exchangeable Na [cmol (p+) kg^{-1}]	10.82	7.86
ESP (%)	37.36	34.84
DTPA-Fe (mg kg^{-1})	28.8	37.72
DTPA-Mn (mg kg^{-1})	5.55	1.76
DTPA-Cu (mg kg^{-1})	2.20	2.39
DTPA-Zn (mg kg^{-1})	0.72	0.55
Gypsum requirement (t ha^{-1})	13.67	10.52

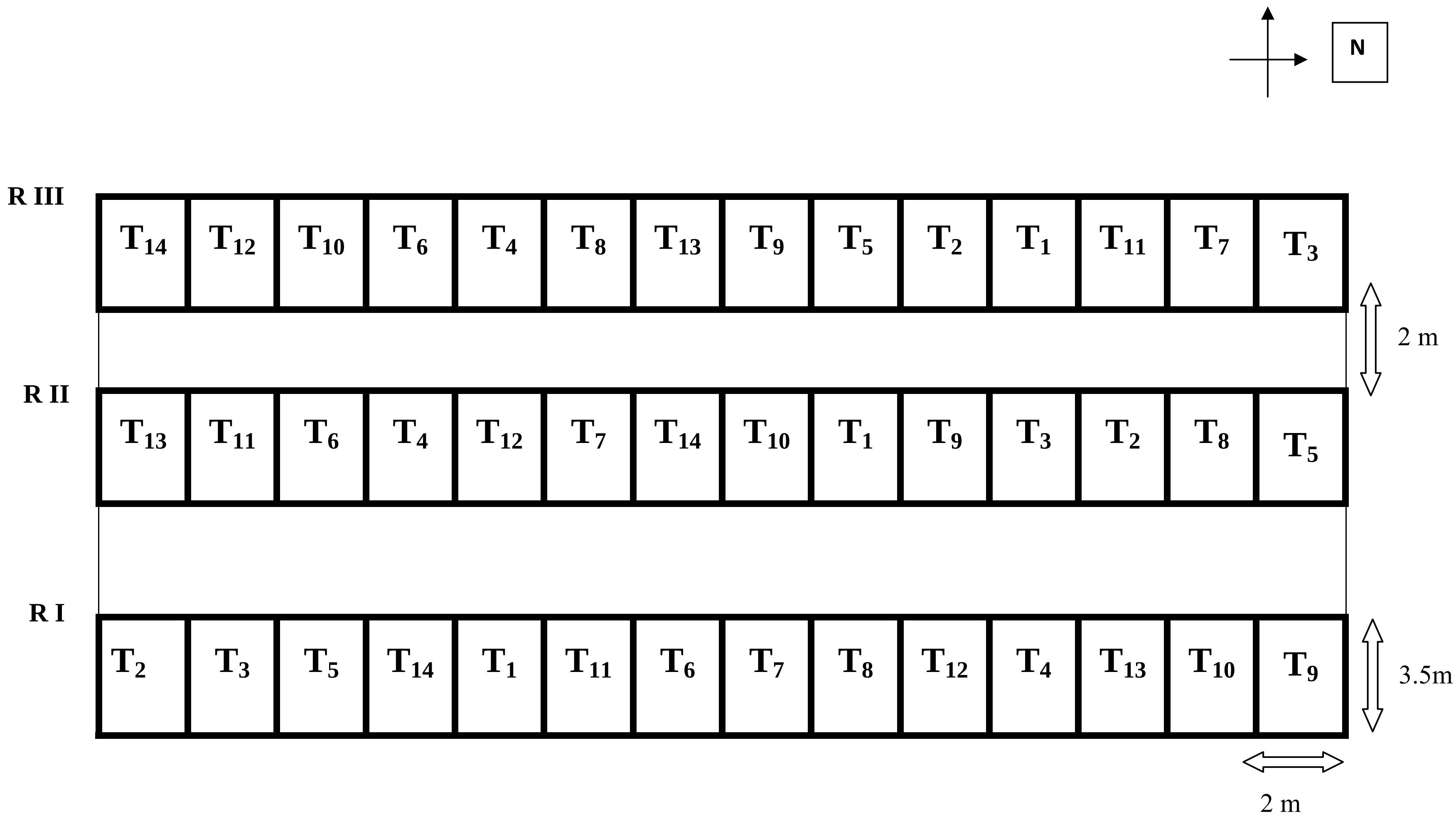

Fig. 3.2 : Plan of layout of filed experiment-II

T_4: RSW @ 50% GR +50% RDN through TSW (4 splits)

T_5: RSW @ 50% GR +100% RDN through TSW (3splits)

T_6: RSW @ 50% GR +100% RDN through TSW (4 splits)

T_7: RSW @ 100% GR+50% RDN through TSW (3 splits)

T_8: RSW @ 100% GR+50% RDN through TSW (4 splits)

T_9: RSW @ 100% GR+100% RDN through TSW (3splits)

T_{10}: RSW @ 100% GR+100% RDN through TSW (4splits)

T_{11}: 100% RDN (50% basal RSW + 50% TSW in 3 splits)

T_{12}: 100% RDN (50% basal RSW + 50% TSW in 4splits)

T_{13}: 150% RDN (50% basal RSW + 50% TSW in 3 splits)

T_{14}: 150% RDN (50% basal RSW + 50% TSW in 4 splits)

Where,

RDN- Recommended Dose of Nitrogen

RDP- Recommended Dose of Phosphorus

RDK- Recommended Dose of Potassium

RSW –Raw Spentwash

TSW- Treated Spentwash (primary treated)

3.3.2.4 Plot size

Gross plot: 3.5 m X 2.0 m = 7.0 m^2

Spacing = 20 X 10 cm

3.3.2.5 Crop and Variety

Paddy (IR-30864) was used as test crop.

3.3.2.6 Imposition of treatments

The land was ploughed with tractor drawn mould board plough followed by harrowing and leveling. Layout was made according to the experimental design and plot size for planting paddy. After digging drainage channels and making bunds, calculated quantity of gypsum and raw spentwash were applied to the plots as per lay out plan one month before planting. Plots were leached with the good quality water and proper drainage was provided to leach out excess salts. The schedule of ferti-irrigation of spentwash and fertilizer application is presented in Table 3.4.

3.3.2.7 Harvest

The crop was harvested plot wise close to the ground level during third week of June 2009, detrashed, bundled and stocked plot wise before recording the yield.

3.3.3 Observations

3.3.3.1 Growth, yield and yield parameters

The bio metric observations like plant height, number of tillers, number of panicles, panicle length, number of seeds per panicle, were recorded as given in section 3.2.3.1.

The grain and straw yield of each treatment was recorded and expressed in quintals per hectare.

3.3.4 Collection of samples

3.3.4.1 Soil sampling

The representative soil samples were collected from each plot at different crop growth stages *viz.,* at tillering, flowering stage and after harvest stage of crop from 0-15 cm depth. Soil samples were shade dried, powdered and analyzed for different parameters following standard procedures as described in Table 3.2

3.3.4.2 Plant sampling

The grain and straw samples were drawn at harvest treatment wise at harvest and analysed as per standard procedures (Table 3.2) for total nutrients content and uptake was calculated.

3.4 Green house experiment III: Effect of Spentwash application of different dilutions on growth and yield of paddy

To study the impact of spentwash of different dilutions (1:1 1:5, 1:10, 1:20, 1:40) a pot experiment was conducted with paddy as test crop mainly to identify the best dilution for paddy crop. Ten kilogram of soil was taken in plastic pot and calculated quantity of primary spentwash (40%) was applied as basal dose based on nitrogen requirement of the crop. After twenty days of application, paddy seedlings were transplanted in each pot. Remaining 60% of recommended nitrogen was provided through spentwash in five different dilutions treatmentwise at 20days, 30days, and 40 days after planting the seedlings.

3.4.1 Treatments: 5

3.4.2 Replications: 3

3.4.3 Design: CRD

3.4.4 Variety: Tanu

3.4.5 Treatment details

T_1: 1:1 Dilution (spentwash: water)

T_2: 1:5, Dilution (spentwash: water)

T_3: 1:10 Dilution (spentwash: water)

T_4: 1:20 Dilution (spentwash: water)

T_5: 1:40 Dilution (spentwash: water)

The bio metric observations like plant height, number of tillers, number of panicles, panicle length and number of seeds per panicle, were recorded treatment wise. The grain and straw yield was recorded treatmentwise and expressed in grams per pot. The grain and straw samples were drawn treatmentwise and analyzed for total nutrients concentration and uptake was calculated.

Table 3.6 : Initial properties of the soils used for green house experiments.

Parameters	Green house Experiment-II	Green house Experiment-III
Place	GKVK,Bangalore	GKVK,Bangalore
Textural class	Sandy clay loam	Sandy clay loam
pH (1:2.5)	7.20	6.18
EC (dS m^{-1})	0.14	0.18
Organic Carbon (%)	0.42	0.39
Available N (kg ha^{-1})	286.73	215.16
Available P_2O_5 (kg ha^{-1})	18.36	19.01
Available K_2O (kg ha^{-1})	273.25	328.43
CEC [c mol (p+) kg^{-1}]	8.56	10.12
Exchangeable Ca [c mol (p+) kg^{-1}]	3.14	2.26
Exchangeable Mg [c mol (p+) kg^{-1}]	1.78	1.03
Exchangeable Na [cmol (p+) kg^{-1}]	0.152	0.116
Available S (mg kg^{-1})	11.86	5.87
DTPA-Fe (mg kg^{-1})	22.75	21.28
DTPA-Mn (mg kg^{-1})	6.45	4.06
DTPA-Cu (mg kg^{-1})	3.87	1.54
DTPA-Zn (mg kg^{-1})	2.25	1.15

3.5 Statistical analysis and interpretation of data

The analysis and interpretation of the data were done using the Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1961). The level of significance used in 'F' and 't' test was P=0.05 probability level and wherever 'F' test was found significant, the 't' test was performed to estimate critical differences among various treatments.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The present investigation “Utilization of spentwash for reclamation of sodic soil and ferti-irrigation studies in Rice” was carried out during 2007-09. This included a pot experiment at GKVK to study the extent of reclamation of sodic and calcareous sodic soils upon use of gypsum and raw spentwash and subsequently the growth and yield of paddy. Based on the result obtained, a field experiment was conducted at VC farm, Mandya to study the extent of reclamation of sodic soil with various level of raw spentwash and inturn the growth and yield of paddy. In the same experiment plot piezometer study was conducted. Second green house experiment was conducted at GKVK on ferti-irrigation studies with spentwash and based on the result obtained the second field experiment was conducted at VC farm, Mandya. Also another green house experiment was conducted at GKVK to study the effect of different dilutions of spentwash application on growth and yield of paddy and on soil properties. The results of the investigations are presented in this chapter.

4.1 Characterization of distillery spentwash

Representative raw and primary treated spentwash samples collected from M/s Chamundeshwari Distilleries Private Limited, K.M.Doddi, Maddur Taluk, Mandya district, at three months interval during August 2007 to August 2008 were analyzed for different parameters and the average values are presented in Table 4.1.

The pH of raw spentwash was 4.11 with the electrical conductivity of 17.70 dS m^{-1}. The total suspended solids (TSS) and total dissolved solids (TDS) was 1.43 per cent and 5.20 per cent respectively. The biological oxygen demand (BOD) and chemical oxygen demand (COD) were 35320 mg L^{-1} and 94650 mg L^{-1} respectively.

The concentration of nitrogen, phosphorus and potassium were 0.19, 0.03, and 0.88 per cent respectively. Spent wash contained calcium, magnesium and sodium to an extent of 2600, 1700, 300.80 mg L^{-1} respectively. The average concentration of iron, manganese, zinc and copper were 18.0, 5.8, 0.83 and 1.2 mg L^{-1} respectively. The sulphates and chloride concentration were 3316 mg L^{-1} and 8510 mg L^{-1}.

Table 4.1 : Physico-chemical properties of untreated raw and primary treated spentwash

Parameters	Raw spent wash	Primary treated spent wash
pH	4.11	7.22
EC (dS m^{-1})	17.70	8.89
BOD (mg L^{-1})	35320	18400
COD(mg L^{-1})	94650	26350
Total N (%)	0.19	0.17
Total P_2O_5 (%)	0.030	0.031
Total K_2O (%)	0.88	1.06
Ca (mg L^{-1})	2600	1759
Mg (mg L^{-1})	1700	1285
Na(mg L^{-1})	300	1093
Total Suspended Solids (%)	6.8	2.41
Total dissolved solids (%)	5.20	1.24
Cl (mg L^{-1})	8510	5939
SO_4(mg L^{-1})	3316	758
Fe (mg L^{-1})	18.0	21.9
Mn (mg L^{-1})	5.8	6.61
Zn (mg L^{-1})	0.83	2.5
Cu (mg L^{-1})	1.2	4.03

The pH of primary treated spentwash was 7.51with the electrical conductivity of 16.8 dS m^{-1}. The total suspended solids (TSS) and total dissolved solids (TDS) were 1.24 per cent and 2.41 per cent respectively. The biological oxygen demand (BOD) and chemical oxygen demand (COD) load were 18400 mg L^{-1} and 26350 mg L^{-1} respectively.

The concentration of nitrogen, phosphorus and potassium were 0.17, 0.031 and 1.06 per cent respectively. The spentwash contained calcium, magnesium and sodium to an extent of 1759.0, 1285.0, 1093 mg L^{-1} respectively. The average concentration of iron, manganese, zinc and copper were 21.9, 6.61, 2.5 and 4.03 mg L^{-1} respectively. The sulphate and iron concentration 758 mg L^{-1} and 5939 mg L^{-1}.

4.2 Studies on utilization of distillery spentwash for reclamation of sodic soils

4.2.1 Green House Experiment I: Effect of raw spentwash and gypsum on reclamation of sodic and calcareous sodic soil

The data pertaining to the effect of different levels of raw spentwash and gypsum application on pH, EC, Exch.Ca+Mg, Na, ESP and lime content of sodic and calcareous sodic soil is presented in Tables 4.2 to 4.3

4.2.1.1 Soil pH

Application of different quantities of raw spentwash and gypsum based on gypsum requirement of soil showed significant difference with respect to soil pH in both sodic and calcareous sodic soil. Reduction in soil pH was maximum in treatments receiving raw spentwash compared to gypsum application. (Tables 4.2)

Maximum reduction in soil pH of sodic soil was noticed in T_6 (RSW@ 7.5 lakh liters ha^{-1} followed by T_7 (RSW@10.0lakh liters ha^{-1}) which was significantly superior over gypsum application. However, application of gypsum @ 100% GR recorded pH of 10.06 which was on par with T_4 (9.90) and T_5 (9.79) which received 2.5 and 5.0 lakh liters of RSW respectively and were significantly superior over gypsum application @ 50%GR (10.22). After 60 days after application, the decrease in pH was maximum in T_5 (9.21 followed by T_6 (9.39) and was significantly superior over T_1 (9.93) and T_2 (9.84).

Table 4.2 : Effect of raw spentwash and gypsum application on pH, EC and exchangeable calcium+magnesium content of sodic and calcareous sodic soil

Treatments	pH(1:2)								EC (dS m^{-1})								Exch.Ca+Mg (c mol(p^+)kg^{-1})							
	Sodic soil				Calcareous sodic soil				Sodic soil				Calcareous sodic soil				Sodic soil				Calcareous sodic soil			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T_1	10.22	9.93	9.84	9.83	8.92	8.87	8.84	8.83	2.32	2.18	1.88	1.82	1.12	1.01	0.91	0.85	7.24	6.53	6.40	6.39	16.22	15.83	15.62	15.41
T_2	10.05	9.84	9.77	9.75	8.62	8.58	8.53	8.52	2.37	2.15	1.95	1.76	1.14	1.09	1.06	1.08	7.33	6.88	6.73	6.54	17.19	16.70	16.30	16.12
T_3	10.06	9.64	9.55	9.52	8.46	8.48	8.45	8.44	2.43	2.06	1.86	1.75	1.15	1.12	1.04	1.05	7.82	7.30	7.29	7.24	18.13	17.85	16.58	16.30
T_4	9.90	9.68	9.54	9.50	8.57	8.45	8.43	8.41	3.86	2.59	2.23	1.83	1.98	1.86	1.48	1.35	8.66	8.08	8.03	7.85	18.22	17.10	16.95	16.41
T_5	9.79	9.21	9.18	9.19	8.33	8.28	8.25	8.24	4.10	3.94	2.72	2.12	3.15	2.84	2.52	1.90	9.65	8.59	8.46	8.22	19.83	18.05	17.52	17.18
T_6	9.64	9.39	9.35	9.32	8.38	8.36	8.34	8.33	5.77	4.17	3.96	2.45	4.20	3.77	3.41	2.72	9.72	8.70	8.53	8.33	22.0	19.95	19.88	19.62
T_7	9.68	9.51	9.53	9.51	8.53	8.44	8.42	8.42	6.41	5.23	4.18	3.96	4.57	4.28	3.93	3.58	9.83	8.93	8.65	8.37	25.0	22.05	23.93	23.10
SEm±	0.056	0.18	0.11	0.07	0.15	0.07	0.22	0.22	0.49	0.228	0.12	0.09	0.31	0.21	0.22	0.22	0.077	0.81	0.48	0.69	0.85	0.45	0.44	0.44
CD p=0.05)	0.232	0.55	0.33	0.23	0.64	0.21	0.67	0.66	1.47	0.67	0.37	0.28	0.93	0.65	0.65	0.65	0.23	2.46	1.47	2.08	2.57	1.35	1.31	1.33

T_1 Gypsum @ 50% GR:
T_2 : Gypsum @ 75% GR
T_3 : Gypsum @ 100% GR
T_4 : Spentwash @ 2.5 lakh liters ha^{-1}
T_5 : Spentwash @ 5.0 lakh liters ha^{-1}
T_6 : Spentwash @ 7.5 lakh liters ha^{-1}
T_7 : Spentwash @ 10.0 lakh liters ha^{-1}

Whereas, significant reduction in pH of calcareous sodic soil was noticed in T_5 (RSW@ 5.0 lakh liters ha^{-1}) followed by T_6 (RSW@7.5 lakh liters ha^{-1}) and was significantly superior over gypsum application. However application of gypsum @ 100% GR recorded pH (8.46) which was significantly superior over gypsum application @ 50%GR (8.92) and 75% GR (8.62). After 60 days after application, the decrease in pH was maximum in T_5 (8.28) followed by T_6 (8.36) and was significantly superior over T_1 (8.87)and T_2 (8.58).

As the days after application progressed to 120 days, there was a slight reduction in soil pH when compared to 30 and 60 days in both the soils. However, at 120 days after application lowest soil pH was recorded in T_5 (9.19) followed by T_6 (9.35) in sodic and in calcareous sodic soil 8.24 (T_5) and 8.33 (T_6) respectively.

4.2.1.2 Electrical Conductivity

The data pertaining to the effect of raw spentwash and gypsum application on electrical conductivity of sodic and calcareous sodic soil is presented in Tables.4.2

Application of raw spentwash at different quantities significantly increased the electrical conductivity of soil compared to gypsum treatments. Significantly highest soil electrical conductivity was recorded in T_7 which received raw spentwash @ 10.0 lakh liters ha^{-1} (6.41 dS m^{-1}) followed by T_6 receiving 7.5 lakh liters ha^{-1} (5.77 dS m^{-1}) and was significantly higher over T_5 (4.10 dS m^{-1}),T_4 (4.10 dS m^{-1}) receiving 5.0 lakh liters $ha^{-1,}$ 2.5 lakh liters ha^{-1} . Application of gypsum slightly increased the soil EC but was not significant compared to raw spentwash application. However, highest EC (2.43 dS m^{-1}) was recorded in T_3 (gypsum at 100%GR) compared to initial value of (1.81 dS m^{-1}).

Significant increase in EC of calcareous sodic soil was noticed in T_7 with RSW@ 10.0 lakh liters ha^{-1} (4.57 dS m^{-1}) followed by T_6 with RSW@ 7.5 lakh liters ha^{-1} recorded significantly higher (4.20 dS m^{-1}) value over gypsum application. However, application of gypsum slightly increased the soil EC but was not significant compared to raw spentwash application. However, gypsum @ 100% GR (T_3) recorded a EC value of 1.15 dS m^{-1}compared to the initial value of 0.64 dS m^{-1}.

At 60 days after application also a similar trend was observed. Significantly highest electrical conductivity was recorded with T_7 (5.23 dS m^{-1}) followed by T_6, T_5, T_4 and was significantly superior over T_3 (2.06 dS m^{-1}), T_2 (2.15 dS m^{-1}), T_1 (2.18 dS m^{-1}). In calcareous sodic soil also, highest electrical conductivity was recorded with T_7 which received raw spentwash @ 10.0 lakh liters ha^{-1} (4.28 dS m^{-1}) followed by T_6 receiving raw spentwash @ 7.5 lakh liters ha^{-1} (3.77 dS m^{-1}), T_5 (2.84 dS m^{-1}) receiving raw spentwash @ 5.0 lakh liters ha^{-1}, T_4 (1.86 dS m^{-1}) which received rawspentwash @ 2.5 lakh liters ha^{-1} and was significantly superior over T_3 (1.12 dS m^{-1}) ,T_2 (1.09 dS m^{-1}),T_1 (1.01 dS m^{-1}).

At 90 and 120 days after application, there was a slight reduction in soil EC compared to 30 and 60 days. However, at 120 days after application, highest soil EC was recorded in T_7 (3.96 dS m^{-1}) followed by T_6 (2.85 dS m^{-1}) and was found to be superior over application of gypsum @100% GR that recorded (1.75 dS m^{-1}). In calcareous sodic soil highest EC was noticed in T_7 (3.58 dS m^{-1}) compared to gypsum @100% GR (0.85 dS m^{-1}).

4.2.1.3 Exchangeable Ca+Mg

The data pertaining to the effect of raw spentwash and gypsum application on Exch.Ca+Mg content of both sodic and calcareous sodic soil is presented in Table.4.2

Application of raw spentwash at different quantities significantly increased the exchangeable Ca+Mg of sodic soil compared to gypsum treatments. Significantly highest soil exchangeable Ca+Mg was recorded in T_7 (9.93 c mol (p+) kg^{-1}) receiving RSW@ 10.0 lakh liters ha^{-1} followed by T_6 (9.72 c mol (p+) kg^{-1}) and T_5 (9.65 c mol (p+) kg^{-1}) which received RSW@ 7.5 lakh liters ha^{-1} and RSW@ 5.0 lakh liters ha^{-1} respectively, but was significantly superior over T_4 (8.08 c mol (p+) kg^{-1}) which received RSW@ 2.5 lakh liters ha^{-1}, T_3 (7.30 c mol (p+) kg^{-1}) which received gypsum @ 100% GR. However, significantly the lowest exchangeable Ca+Mg was recorded in T_1 (6.53 c mol (p+) kg^{-1}) which received gypsum @75% GR.

Similarly, in calcareous sodic soil, significantly highest soil exchangeable Ca+Mg was recorded in T_7 receiving RSW@ 10.0 lakh liters ha^{-1} (25.0 c mol (p+) kg^{-1}) followed by T_6 receiving RSW@ 7.5 lakh liters ha^{-1} (22.0 c mol (p+) kg^{-1}) but was significantly superior over the treatment which received RSW@ 5.0 lakh liters ha^{-1} (T_5) (19.83 c mol (p+) kg^{-1}),T_4 (18.22 c mol (p+) kg^{-1}) and T_3 (18.13 c mol (p+) kg^{-1}) However, significantly the lowest exchangeable Ca+Mg was recorded in T_1 (16.22 c mol (p+) kg^{-1}) which received gypsum @50% GR.

At 60 days after spentwash application, also a similar trend was followed in both the soils. Significantly highest (9.83 c mol (p+) kg^{-1}) exchangeable Ca+Mg was recorded with T_7 which received RSW@ 10.0 lakh liters ha^{-1} followed by T_6 (9.70 c mol (p+) kg^{-1}) receiving RSW@ 7.5 lakh liters ha^{-1}. The treatment T_5 (RSW@5.0 lakh liters ha^{-1}) recorded Ca+Mg content of 9.59 c mol (p+) kg^{-1} and was significantly superior over T_2 (6.73 c mol (p+) kg^{-1}),T_1 (6.40 c mol (p+) kg^{-1}) which received gypsum@ 75 and 50% GR.

In calcareous sodic soil significantly highest exchangeable Ca+Mg was recorded with T_7 (22.05 c mol (p+) kg^{-1}) followed by T_6 (19.95 c mol (p+) kg^{-1}). T_3 (17.85 c mol (p+) kg^{-1}) and was found to be on par with T_4 (17.10 c mol (p+) kg^{-1}) and T_5 (18.05 c mol (p+) $kg^{-1)}$ significantly superior over T_2 (16.70 c mol (p+) kg^{-1}), T_1 (15.83 c mol (p+) kg^{-1}).

At 90 and 120 days after application, there was a slight reduction in soil exchangeable Ca+Mg compared to 30 and 60 days after application. However, at 120 days after application, highest exchangeable Ca+Mg was recorded in T_7 (9.57 c mol (p+) kg^{-1}) followed by T_6 (9.48 c mol (p+) kg^{-1}) and was found to be superior over application of gypsum @100% GR which recorded 6.82 c mol (p+) kg^{-1}. Similarly, in calcareous sodic soil highest exchangeable Ca+Mg was recorded in T_7 (23.10 c mol (p+) kg^{-1}) followed by T_6 (19.62 c mol (p+) kg^{-1})

4.2.1.4 Exchangeable Na

The application of raw spentwash at different quantities significantly decreased the exchangeable sodium content of sodic and calcareous sodic soil compared to gypsum treatments (Tables 4.3).

At 30 days after application, lowest exchangeable sodium content in sodic soil was recorded in T_5 (5.43 c mol (p+) kg^{-1}) followed by T_4 (5.59 c mol (p+) $kg^{-1)}$ and T_3 (5.76 c mol (p+) kg^{-1}) respectively. Significantly highest exchangeable sodium was recorded in T_1 (6.71 c mol (p+) kg^{-1}), T_2 (6.31 c mol (p+) kg^{-1}), T_6 (6.95 c mol (p+) kg^{-1}) and T_7 (7.10 c mol (p+) kg^{-1}). At 60, 90 and 120 days after application there was slight reduction in soil exchangeable sodium compared to samples collected at 30 days. However, at 120 days after application, highest exchangeable sodium was recorded in T_7 (6.97 c mol (p+) kg^{-1}) followed by T_6 (6.73 c mol (p+) kg^{-1}).

In calcareous sodic soil significantly lowest soil exchangeable sodium was recorded in T_5 (8.38 c mol (p+) kg^{-1}) followed by T_4 (8.51 c mol (p+) kg^{-1}) and was significantly superior over T_2, T_3 and was on par with T_6 (9.12 c mol (p+) kg^{-1}) and T_7 (9.28 c mol (p+) kg^{-1}). Significantly highest exchangeable sodium was recorded in T_1 (9.78 c mol (p+) kg^{-1}) which received gypsum @ 50% GR. At 60 days after application also similar trend was followed, significantly highest exchangeable sodium was recorded with T_1 (8.79 c mol (p+) kg^{-1}) followed by T_2 (8.59 c mol (p+) kg^{-1}). Gypsum@ 100% GR (T_3) recorded exchangeable sodium content of (8.44 c mol (p+) kg^{-1}) and was found on par with,T_4 (RSW @ 2.5 lakh liter ha^{-1}) (8.34 c mol (p+) kg^{-1}),T_5 (RSW @ 5.0 lakh liter ha^{-1}) which recorded 8.28 c mol (p+) kg^{-1} .Whereas, T_7 and T_6 treatments recorded exchangeable sodium content 9.21 c mol (p+) kg^{-1} and 9.05 c mol (p+) kg^{-1} respectively.

At 90 and 120 days after application, there was slight reduction in exchangeable sodium content of soil compared to 30 and 60 days. However, highest exchangeable sodium was recorded in T_7 receiving RSW @ 10 lakh liter ha^{-1}(8.99 c mol (p+) kg^{-1}) followed by T_6 receiving RSW @ 7.5 lakh liter ha^{-1} (8.68 c mol (p+) kg^{-1}).

Table 4.3 : Effect of raw spentwash and gypsum application on exchangeable sodium, exchangeable percentage & lime content of sodic and calcareous sodic soil.

Treatments	Exch. Na (c mol (p^+) kg^{-1})								ESP (per cent)								Lime content (per cent)			
	Sodic soil				Calcareous sodic soil				Sodic soil				Calcareous sodic soil				Calcareous sodic soil			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T_1	9.78	8.79	8.74	8.79	6.71	6.65	6.42	6.40	31.37	29.50	26.51	25.76	24.20	23.87	22.52	22.47	8.23	8.20	8.21	8.22
T_2	9.63	8.59	8.51	8.55	6.31	6.25	6.23	6.22	29.75	28.82	24.87	24.03	23.71	21.18	20.71	20.63	8.26	8.22	8.23	8.24
T_3	9.48	8.44	8.34	8.13	5.76	5.59	5.52	5.47	28.97	26.51	23.25	23.08	21.23	19.37	19.29	19.07	8.27	8.26	8.22	8.25
T_4	8.51	8.34	8.33	8.18	5.59	5.42	5.39	5.26	28.40	25.86	23.67	23.11	20.71	19.09	18.91	18.98	6.36	6.27	6.17	6.08
T_5	8.38	8.28	8.00	7.95	5.43	5.26	5.18	5.11	27.30	24.69	22.78	20.38	19.67	18.46	18.35	18.29	5.96	5.65	5.50	5.39
T_6	9.12	9.05	8.74	8.99	6.95	6.83	6.78	6.73	28.64	26.85	25.39	24.83	20.85	19.79	19.52	19.46	5.40	5.35	5.29	5.25
T_7	9.28	9.21	8.92	8.68	7.10	7.08	7.02	6.97	29.50	28.38	27.63	27.38	21.29	20.92	20.84	20.66	5.36	5.24	5.12	5.06
SEm±	0.47	0.13	0.14	0.12	0.22	0.22	0.49	0.44	0.62	0.88	1.38	0.93	0.66	0.79	0.66	0.44	0.45	0.73	0.91	1.09
CD (p=0.05)	1.00	0.28	0.30	0.26	0.66	0.66	1.47	1.32	1.33	1.88	2.95	1.98	1.99	2.38	1.98	1.33	1.36	2.19	2.74	3.30

T_1 Gypsum @ 50% GR:
T_2 : Gypsum @ 75% GR
T_3 : Gypsum @ 100% GR
T_4 : Spentwash @ 2.5 lakh liters ha^{-1}
T_5 : Spentwash @ 5.0 lakh liters ha^{-1}
T_6 : Spentwash @ 7.5 lakh liters ha^{-1}
T_7 : Spentwash @ 10.0 lakh liters ha^{-1}

4.2.1.5 Exchangeable Sodium Percentage

Application of raw spentwash and gypsum at different quantities significantly decreased the exchangeable sodium percentage of soil compared to gypsum treatments (Tables 4.3).

Significantly lowest soil exchangeable sodium percentage was recorded in T_5 (27.30 per cent) which received RSW @ 5.0 lakh liters ha^{-1} and was significantly superior over T_4 (28.40 per cent), T_6 (28.64 per cent) and T_7 (29.50 per cent) which received RSW @ 2.5 lakh liters ha^{-1} , 7.5 lakh liters ha^{-1} and 10.0 lakh liters ha^{-1} respectively. Among the gypsum applied treatments, maximum reduction in exchangeable sodium percentage was in T_3 (28.97 per cent) followed by T_2 and was superior over T_1 (31.37 per cent). Similarly, in calcareous sodic soil, lowest exchangeable sodium percentage was recorded in T_5 (19.67 per cent) and was significantly superior over T_4 (20.71 per cent), T_6 (20.85 per cent) and T_7 (21.29 per cent).

At 60 days after application also, a similar trend was followed. Significantly highest exchangeable sodium percentage was recorded with T_1 (29.50 per cent) followed by T_2 (28.82 per cent) and was on par with T_7 and T_6 which recorded (26.85 per cent) and 28.38 respectively. The lowest exchangeable sodium percentage of (24.69 per cent) was recorded in T_5 (RSW @ 5.0 lakh liter ha^{-1}) and was found on par with T_4 (RSW @ 5.0 lakh liter ha^{-1}) (25.86 per cent). Similarly in calcareous sodic soil, lowest exchangeable sodium percentage of (18.46 per cent) was recorded in T_5 (RSW @ 5.0 lakh liter ha^{-1}) and was found on par with, T_4 (RSW @ 5.0 lakh liter ha^{-1}) (19.09 per cent) and found significantly superior over T_6 (19.79 per cent), T_7 (20.92 per cent) and T_3 (19.37 per cent).

At 90 and 120 days after application, there was slight reduction in exchangeable sodium percentage of soil compared to 30 and 60 days. However, in sodic soil lowest exchangeable sodium percentage of 20.38 per cent was recorded in T_5 which received raw $_{spentwash}$ @ 5.0 lakh liters ha^{-1}. In calcareous sodic soil also a similar trend of results was observed.

4.2.1.6 Lime content of calcareous sodic soil

Application of different quantities of raw spentwash significantly decreased the lime content of soil compared to gypsum treatments (Table 4.3).

Significantly lowest lime content was recorded in T_7 with RSW @ 10.0 lakh liter ha^{-1} (5.36 per cent) followed by T_6 (5.40 per cent) receiving RSW @ 7.5 lakh liter ha^{-1}, T_5 (5.96 per cent) RSW @ 5.0 lakh liter ha^{-1} and was significantly superior over gypsum applied treatments which recorded 8.27 per cent followed by $T_{2,}$ T_1 which were not significant.

At 60 days after application, also a similar trend was followed. Significantly lowest lime content (5.24 per cent) was recorded in T_7 (RSW @ 10.0 lakh liter ha^{-1}) followed by T_6 (RSW @ 7.5 lakh liter ha^{-1}) (5.35 per cent) and T_5 (5.65 per cent).

At 90 and 120 days after application, there was a slight reduction in lime content of soil compared to 30 and 60days. However, the highest (8.22 per cent) lime content was recorded in T_1 and lowest in T_7 (5.06 per cent).

4.2.1.7 Chemical composition of leachate

The data pertaining to chemical composition of leachate collected after 30, 60 and 90 days of raw spentwash application is presented in Tables 4.4 to 4.7. Increasing the quantity of RSW application increased the soluble salts content in leachate compared to gypsum application in both sodic and calcareous sodic soil.

In general, pH, EC, Ca+Mg, Na^+, HCO_3^-, Cl^- , SO_4^{2-} increased with increase in the rate of spentwash application. Among the cations, the quantity of sodium leached was more compared to calcium and magnesium and among the anions HCO_3^- was leached more compared to chlorides and sulphates.With increase in days after raw spentwash application soluble salt concentration decreased over period. Increase in soluble salt concentration was significantly superior over gypsum treatments.

Table 4.4 : Effect of raw spentwash and gypsum application on pH, EC, Ca+Mg and Na content of leachate from sodic soil.

Treatments	pH				EC dS m^{-1}				Ca+Mg (meq L^{-1})				Na (meq L^{-1})			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T_1	8.45	8.31	8.19	8.13	1.62	1.43	1.10	0.89	9.64	8.97	8.5	8.64	9.77	9.65	8.97	8.83
T_2	8.52	8.44	8.24	8.17	1.88	1.65	1.26	0.95	11.96	9.96	9.0	9.02	9.92	9.80	9.22	8.87
T_3	8.86	8.50	8.36	8.19	2.14	1.96	1.71	1.07	13.45	10.96	10.5	10.21	10.24	10.18	9.42	8.95
T_4	9.23	9.03	8.93	8.55	10.45	8.83	6.83	3.43	15.94	13.95	13.0	12.45	14.73	12.40	10.12	9.42
T_5	9.40	9.12	9.05	8.72	13.05	11.93	8.94	4.02	18.93	16.44	15.0	13.81	15.37	13.50	11.27	10.36
T_6	9.68	9.26	9.12	8.99	17.37	14.60	10.61	5.73	21.92	18.43	17.0	15.83	18.14	14.77	12.50	11.22
T_7	9.86	9.54	9.30	9.13	19.77	16.67	11.69	8.00	23.91	21.42	19.0	16.57	20.33	15.63	13.77	12.48
SEm±	0.31	0.30	0.14	0.09	1.66	1.46	1.00	0.09	1.20	0.75	0.43	0.27	0.31	0.24	0.15	0.14
CD (p=0.05)	0.66	0.93	0.29	0.27	3.55	4.42	3.01	0.28	3.63	2.28	1.32	0.81	0.95	0.73	0.46	0.43

T_1 : Gypsum @ 50% GR
T_2 : Gypsum @ 75% GR
T_3 : Gypsum @ 100% GR
T_4 : Spentwash @ 2.5 lakh liters ha^{-1}
T_5 : Spentwash @ 5.0 lakh liters ha^{-1}
T_6 : Spentwash @ 7.5 lakh liters ha^{-1}
T_7 : Spentwash @ 10.0 lakh liters ha^{-1}

Table 4.5 : Effect of raw spentwash and gypsum application on chlorides, sulphates, bicarbonates content of leachate from sodic soil

Treatments	Cl^- (meq L^{-1})				SO_4^{2-} (meq L^{-1})				HCO_3^- (meq L^{-1})			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T_1	1.12	1.08	0.96	0.85	1.64	1.53	1.48	1.42	1.83	1.61	1.57	1.51
T_2	1.24	1.16	1.05	0.93	2.05	1.86	1.66	1.51	2.00	1.85	1.66	1.61
T_3	1.35	1.23	1.18	1.12	2.20	2.11	2.05	2.03	2.31	2.13	1.73	1.69
T_4	2.52	1.86	1.52	1.43	3.34	3.21	3.15	3.05	6.32	5.80	5.03	4.96
T_5	3.24	2.95	2.31	1.90	4.38	4.27	4.09	3.68	9.72	8.90	7.39	7.03
T_6	4.13	3.72	3.09	3.24	6.67	5.81	5.09	5.18	11.64	10.61	9.85	9.63
T_7	6.06	5.15	4.76	4.63	7.18	6.75	6.63	6.41	13.32	12.43	10.68	11.79
SEm±	0.52	0.36	0.28	0.24	0.45	0.44	0.33	0.44	0.44	0.43	0.26	0.44
CD (p=0.05)	1.59	1.10	0.85	0.72	1.35	1.32	1.01	1.32	1.32	1.31	0.78	1.32

T_1 : Gypsum @ 50% GR
T_2 : Gypsum @ 75% GR
T_3 : Gypsum @ 100% GR
T_4 : Spentwash @ 2.5 lakh liters ha^{-1}
T_5 : Spentwash @ 5.0 lakh liters ha^{-1}
T_6 : Spentwash @ 7.5 lakh liters ha^{-1}
T_7 : Spentwash @ 10.0 lakh liters ha^{-1}

Table 4.6 : Effect of raw spentwash and gypsum application on pH, EC, Ca+Mg and Na content of leachate from calcareous sodic soil

Treatments	pH				EC (dS m^{-1})				Ca+Mg (meq L^{-1})				Na (meq L^{-1})			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T_1	7.41	7.38	7.32	7.28	0.83	0.82	0.83	0.83	14.5	13.45	12.5	10.5	1.86	1.65	1.23	1.12
T_2	7.55	7.46	7.24	7.22	0.89	0.84	0.85	0.82	16.0	14.45	13.5	11.25	2.56	2.14	1.96	1.84
T_3	7.58	7.57	7.41	7.36	0.91	0.89	0.86	0.84	18.5	16.69	15.5	12.5	3.02	2.87	2.02	1.86
T_4	8.64	8.26	8.24	8.21	3.84	3.26	2.83	1.92	20.5	19.43	18.5	15.5	6.56	5.78	2.65	1.38
T_5	8.89	8.34	8.29	8.24	4.64	4.08	3.91	2.78	22.0	19.31	19.5	16.25	8.14	6.89	4.18	2.39
T_6	9.14	8.72	8.36	8.32	6.42	6.22	5.89	4.62	24.5	22.07	20.50	18.5	10.25	7.36	5.21	3.96
T_7	9.50	9.38	9.15	9.08	7.26	7.10	6.72	6.14	30.5	28.40	24.84	22.25	12.58	10.43	8.63	5.94
SEm±	0.49	0.44	0.44	0.65	0.65	0.44	0.53	0.49	0.65	0.51	0.44	0.42	0.49	0.44	0.49	0.31
CD (p=0.05)	1.48	1.31	1.31	1.97	1.97	1.32	1.60	1.47	1.97	1.54	1.31	1.28	1.47	1.31	1.47	0.93

T_1 : Gypsum @ 50% GR
T_2 : Gypsum @ 75% GR
T_3 : Gypsum @ 100% GR
T_4 : Spentwash @ 2.5 lakh liters ha^{-1}
T_5 : Spentwash @ 5.0 lakh liters ha^{-1}
T_6 : Spentwash @ 7.5 lakh liters ha^{-1}
T_7 : Spentwash @ 10.0 lakh liters ha^{-1}

Table 4.7 : Effect of raw spentwash and gypsum application on chlorides, sulphates, bicarbonates content of leachate from calcareous sodic soil

Treatments	Cl^- (meq L^{-1})				SO_4^{2-} (meq L^{-1})				HCO_3^- (meq L^{-1})			
	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days	30 days	60 days	90 days	120 days
T_1	1.85	1.72	1.68	1.63	1.82	1.65	1.58	1.42	2.6	2.39	2.17	2.4
T_2	2.12	2.06	1.96	1.85	2.34	2.18	2.06	1.84	3.1	2.79	2.23	2.5
T_3	2.23	2.15	2.11	2.08	2.56	2.37	2.13	2.10	3.5	3.19	2.81	3.2
T_4	3.85	3.62	3.35	3.06	4.58	4.32	4.25	4.15	5.6	5.32	4.83	4.52
T_5	5.69	5.28	5.04	4.95	6.35	6.18	6.12	5.97	9.2	8.83	7.64	8.35
T_6	6.12	5.83	5.46	5.21	7.29	7.11	6.89	6.66	10.8	9.24	8.91	9.89
T_7	6.78	6.65	6.33	6.18	8.12	7.87	7.56	7.28	14.8	11.50	10.14	11.64
SEm±	0.54	0.26	0.31	0.55	0.31	0.54	0.49	0.54	0.87	0.44	0.54	0.85
CD (p=0.05)	1.63	0.77	0.93	1.66	0.93	1.62	1.48	1.62	2.63	1.32	1.62	2.55

T_1 : Gypsum @ 50% GR
T_2 : Gypsum @ 75% GR
T_3 : Gypsum @ 100% GR
T_4 : Spentwash @ 2.5 lakh liters ha^{-1}
T_5 : Spentwash @ 5.0 lakh liters ha^{-1}
T_6 : Spentwash @ 7.5 lakh liters ha^{-1}
T_7 : Spentwash @ 10.0 lakh liters ha^{-1}

Significantly higher values were recorded for each parameter at 30days after application in raw spentwash received pots and thereafter and over a period of time (120days) significant reduction was noticed.

At 30 days after application, significantly highest pH, EC, Ca^{2+}, Mg^{2+} HCO_3^-, Cl^- and SO_4^{2-} , Na^+, of 9.86, 19.77 dS m^{-1}, 23.91 meq L^{-1}, 20.33 meq L^{-1}, 13.32 meq L^{-1}, 6.06 meq L^{-1}, 7.18 meq L^{-1} respectively were recorded in T_7 which received raw spentwash @ 10.0 lakh liters ha^{-1} followed by T_6 T_5 and T_4 compared to gypsum application. After 120days after application, the values got reduced to 9.13, 8.0dS m^{-1}, 16.57 meq L^{-1}, 12.48 meq L^{-1}, 11.79 meq L^{-1}, 4.63 meq L^{-1}, 6.41 meq L^{-1}respectively.

The leachate collected at different intervals in calcareous sodic soil also followed similar trend. At 30days after application significantly highest pH, EC, Ca^{2+}, Mg^{2+} HCO_3^- , $Cl^-$and SO_4^{2-} , Na^+, of 9.50, 7.10 dS m^{-1}, 30.5 meq L^{-1}, 12.5 meq L^{-1},14.8 meq L^{-1},6.78 meq L^{-1},8.12 meq L^{-1} respectively were recorded in T_7 which received raw spentwash @ 10.0 lakh liters ha^{-1} followed by T_6 (RSW @ 7.5 lakh liters ha^{-1}),T_5 (RSW @ 5.0 lakh liters ha^{-1}) and T_4 (RSW @ 2.5 lakh liters ha^{-1}) compared to gypsum application. After 120days after application, the values got reduced to 9.08, 6.14 dS m^{-1}, 22.25 meq L^{-1}, 5.94 meq L^{-1}, 11.64 meq L^{-1}, 6.18 meq L^{-1}, 7.28 meq L^{-1}respectively.

4.2.2 Field Experiment I - Effect of raw spentwash on reclamation of sodic soil and its effect on growth and yield of paddy at V C Farm, Mandya

4.2.2.1 Growth parameters

4.2.2.1.1 Plant height

The data pertaining to the effect of raw spentwash and gypsum on plant height after reclamation of sodic soil are presented in Table.4.8. There was a significant increase in plant height with the application raw spentwash than gypsum and control treatments. The highest plant height of 66.98 cm was recorded with T_5 treatment receiving 7.5 lakh liters ha^{-1} followed by T_4 (5.0 lakh liters ha^{-1}) and T_3 (2.5 lakh liters ha^{-1}) which recorded 65.19 cm, 58.35 cm respectively and their effect was on par with each other. The lowest plant height (37.91cm) was recorded in the treatment (T_1) with recommended NPK

Table 4.8 : Effect of raw spentwash and gypsum application on growth and yield parameters, grain & straw yield of paddy at VC farm, Mandya (Field experiment I).

Treatments	Plant height (cm)	No. of productive tillers	No. of Panicles	Length of panicle	No. of seeds /panicle	Thousand grain weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1	37.91	8.48	4.99	14.75	106.04	19.43	17.48	18.30
T_2	47.58	12.47	10.48	17.52	123.12	43.80	36.32	37.07
T_3	58.35	13.97	11.97	19.37	132.29	47.66	39.69	42.65
T_4	65.19	20.95	17.96	23.06	156.51	58.85	45.18	51.62
T_5	66.98	17.96	13.97	21.21	149.92	56.42	44.75	54.86
SEm±	3.604	1.31	1.269	0.677	3.35	1.69	1.401	1.876
CD(p=0.05)	10.822	4.05	3.785	2.089	10.33	5.22	4.318	5.783

T_1: Recommended NPK (without amendment)
T_2: Gypsum @100% GR + Recommended NPK
T_3: Raw Spentwash @ 2.5 lakh liters ha^{-1}+ balance of P
T_4: Raw Spentwash @ 5.0 lakh liters ha^{-1} + balance of P
T_5: Raw Spentwash @ 7.5 lakh liters ha^{-1} + balance of P

without amendment and it was on par with T_2 (gypsum @100% GR + Recommended NPK).

4.2.2.1.2 Number of productive tillers

The results pertaining to the effect of raw spentwash and gypsum on the number of productive tillers are presented in Table 4.8. Significant increase in the number of productive tillers was recorded with the application of raw spentwash over gypsum application and control. The highest (20.95) number of productive tillers was recorded in T_4 treatment receiving 5.0 lakh liters ha^{-1} and was on par with T_5 treatment (17.96) which received 7.5 lakh liters ha^{-1} whereas application of gypsum @ 100% GR recorded 12.47 number of productive tillers and was on par with T_3 treatment receiving 2.5 lakh liters ha^{-1} (13.97). The lowest (8.48) number of productive tillers was recorded in T_1 (recommended NPK without amendment).

4.2.2.1.3 Number of panicles

The number of panicles obtained due to application of raw spentwash and gypsum are presented in Table 4.8. There was significant increase in the number of panicles with the application of raw spentwash. The highest number of panicles (17.96) was recorded in T_4 treatment receiving 5.0 lakh liters ha^{-1} followed by T_5 (13.97) which received 7.5 lakh liters $ha^{-1.}$ Application of gypsum @ 100% GR recorded 10.48 number of panicles and was on par with T_3 treatment receiving 2.5 lakh liters ha^{-1} (11.97).The lowest (4.99) number of productive tillers was recorded in T_1 (recommended NPK without amendment).

4.2.2.1.4 Length of panicle

The data pertaining to effect of raw spentwash and gypsum on length of panicle after reclamation of sodic soil are presented in Table 4.8. There was significant increase in length of panicle with the application raw spentwash than gypsum and control treatments. The highest length of panicle (23.06 cm) was recorded with T_4 treatment receiving 5.0 lakh liters ha^{-1} followed by T_5 (RSW@7.5 lakh liters ha^{-1}) which recorded (21.21cm) and were on par with each other. The lowest length of panicle (14.75cm) was recorded in recommended NPK without amendment. Application of gypsum @100% GR + recommended NPK recorded 17.52 cm which was on par with T_3 (2.5 lakh liters ha^{-1}) (19.37 cm).

4.2.2.1.5 Number of seeds per panicle

Application of raw spentwash and gypsum significantly influenced the No. of seeds per panicle (Table 4.8). The highest number of seeds per panicle was recorded with the application raw spentwash @ 5.0 lakh liters ha^{-1} (156.51) and was on par with the treatment receiving raw spentwash @ 7.5 lakh liters ha^{-1}. Application of gypsum @ 100%GR recorded (123.12) number of seeds per panicle which was on par with raw spentwash @ 2.5 lakh liters ha^{-1} (132.29). Significantly lowest (106.04) number of seeds per panicle was recorded in control treatment.

4.2.2.1.6 Thousand grain weight

The data pertaining to the effect of raw spentwash and gypsum on thousand grain weight after reclamation of sodic soil are presented in Table 4.8. There was a significant increase in thousand grain weight with the application of raw spentwash than gypsum and control. The highest thousand grain weight of 58.85 g was recorded with T_4 treatment receiving rawspentwash @ 5.0 lakh liters ha^{-1} followed by T_5 (RSW@7.5 lakh liters ha^{-1}) which recorded (56.42 g) and were on par with each other. The lowest thousand grain weight (19.43 g) was recorded in Recommended NPK without amendment. Application of gypsum @100% GR + recommended NPK recorded 43.80 g which was on par with T_3 (2.5 lakh liters ha^{-1}) (47.66 g).

4.2.2.2 Yield

4.2.2.2.1 Grain yield

The data on grain yield as influenced by the use of raw spentwash and gypsum for reclamation of sodic soil in paddy is presented in Table 4.8. Application of raw spentwash at 5.0lakh liters ha^{-1} recorded significantly higher yield (45.18 q ha^{-1}) but was on par with 7.5 lakh liters ha^{-1}(44.75 q ha^{-1}). Raw spentwash application @2.5 lakh liters ha^{-1} recorded significantly lower grain yield (39.69 q ha^{-1}) compared to T_4 & T_5 but was on par with gypsum @100%GR (36.32 q ha^{-1}). The lowest (17.48 q ha^{-1}) grain yield was recorded in T_1 (recommended NPK without amendment).

4.2.2.2.2 Straw yield

Application of raw spentwash and gypsum significantly influenced the straw yield (Table 4.8). The straw yield also followed a similar trend as that of paddy grain yield, recording highest straw yield with raw spentwash @ 7.5 lakh liters ha^{-1} (54.86 q ha^{-1}) and which was on par with the treatment receiving 5.0 lakh liters ha^{-1} (51.62 q ha^{-1}). Application of gypsum @100% GR recorded (37.07 q ha^{-1}) which was on par with the yield of raw spentwash 2.5 lakh liters ha^{-1} (42.65 q ha^{-1}). Significantly lowest (18.30 q ha^{-1}) straw yield was recorded in control treatment.

4.2.2.3 Nutrient uptake by paddy

4.2.2.3.1 Nitrogen

The data pertaining to nitrogen (N) uptake at harvest is presented in Table 4.9. Increased application of raw spentwash significantly increased N uptake compared to the treatments receiving gypsum and recommended dose of NPK. N uptake was significantly highest (113.07 kg ha^{-1}) in T_5 receiving raw spentwash @7.5 lakh liters ha^{-1} compared to T_2 (Gypsum @100%GR) (92.15 kg ha^{-1}) and was on par with T_4 (RSW @ 5.0 lakh liters ha^{-1}) (111.31 kg ha^{-1}) and T_3 (RSW @ 2.5 lakh liters ha^{-1}) (106.32 kg ha^{-1}). N uptake in control (T_1) recorded significantly lowest (82.65 kg ha$^{-1)}$ than other treatments.

4.2.2.3.2 Phosphorus

The phosphorus (P) uptake by paddy at harvest is presented in Table 4.9. A significant increase in P uptake (18.85 kg ha^{-1}) was noticed in T_5 raw spentwash @7.5 lakh liters ha^{-1} which was on par with T_4 (RSW @ 5.0lakh liters ha^{-1}) recording 18.06 kg ha^{-1}. Significantly lowest (14.06 kg ha^{-1}) P uptake was recorded in T_3 (RSW @ 2.5 lakh liters ha^{-1}) compared to T_4 & T_5 but was on par with the treatment T_2 (Gypsum @100%GR+Rec.NPK) (13.13 kg ha^{-1}). Lowest P uptake of 8.81 kg ha^{-1} was recorded in T_1 (Rec.NPK and no amendment)

Table 4.9 : Effect of raw spentwash and gypsum application on nutrients uptake by paddy crop at VC farm, Mandya (Field experiment I)

Treatments	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	Ca ($kg\ ha^{-1}$)	Mg ($kg\ ha^{-1}$)	S ($kg\ ha^{-1}$)	Fe ($mg\ kg^{-1}$)	Mn ($mg\ kg^{-1}$)	Zn ($mg\ kg^{-1}$)	Cu ($mg\ kg^{-1}$)
T_1	82.65	8.81	82.94	11.93	4.71	8.84	12.52	11.06	1.75	2.86
T_2	92.15	13.13	95.00	24.48	7.01	12.77	38.16	25.17	3.89	6.02
T_3	106.32	14.06	109.40	26.52	9.61	15.03	46.93	32.19	4.45	6.92
T_4	111.31	18.06	115.86	30.72	12.65	17.91	66.79	49.08	5.71	8.13
T_5	113.07	18.85	123.88	31.61	13.69	18.82	66.62	49.22	5.47	8.55
SEm±	1.84	0.58	3.03	1.06	0.80	0.15	4.06	1.3	0.13	0.23
CD(p=0.05)	5.69	1.79	9.36	3.29	2.48	0.46	12.53	4.2	0.41	0.68

T_1: Recommended NPK (without amendment)
T_2: Gypsum @100% GR + Recommended NPK
T_3: Raw Spentwash @ 2.50 lakh liters ha^{-1}
T_4: Raw Spentwash @ 5.0 lakh liters ha^{-1}
T_5: Raw Spentwash @ 7.5 lakh liters ha^{-1}

4.2.2.3.3 Potassium

A significant difference in the potassium (K) uptake was found due to raw spentwash and gypsum application to paddy crop (Table 4.9.). Increased application of raw spentwash significantly increased K uptake compared to the treatments receiving gypsum and recommended dose of NPK. K uptake was significantly highest (123.88 kg ha^{-1}) in T_5 receiving raw spentwash @7.5 lakh liters ha^{-1} compared to T_2 (gypsum @100% GR) (95.00 kg ha^{-1}) and was on par with T_4 (RSW @ 5.0 lakh liters ha^{-1}) (115.86 kg ha^{-1}) and T_3 (RSW @ 2.50 lakh liters ha^{-1}) (109.40 kg ha^{-1}). Significantly lowest (82.94 kg ha$^{-1)}$ uptake of K was recorded in control (T_1: Rec.NPK no amendment) compared to other treatments.

4.2.2.3.4 Calcium

The data pertaining to calcium (Ca) uptake by paddy at harvest is presented in Table 4.9. Application of raw spentwash and gypsum significantly influenced Ca uptake in paddy recording highest (31.71 kg ha^{-1}) value with application of raw spentwash at 7.5 lakh liters ha^{-1} followed by RSW @ 5.0 lakh liters ha^{-1} (30.72 kg ha^{-1}). Application of gypsum @ 100% GR recorded 24.48 kg ha^{-1} and was on par with raw spentwash at 2.5 lakh liters ha^{-1} (26.52 kg ha^{-1}) and significantly lower uptake was recorded in control (T_1:Rec.NPK and no amendment).

4.2.2.3.5 Magnesium

The data on magnesium (Mg) uptake at harvest of paddy as influenced by raw spentwash and gypsum application is presented in Table 4.9. The highest Mg uptake (13.69 kg ha^{-1}) was found with application of raw spentwash at 7.5 lakh liters ha^{-1} followed by raw spentwash at 5.0 lakh liters ha^{-1} (12.65 kg ha^{-1}). Application of gypsum 100% GR recorded 7.01 kg ha^{-1} and was on par with T_3 (2.5 lakh liters ha^{-1}) (9.61 kg ha^{-1}). Application of rec.NPK (no amendment) recorded significantly lowest (4.71 kg ha^{-1}) uptake of Mg.

4.2.2.3.6 Sulphur

The effect of raw spentwash and gypsum application on sulphur (S) uptake is presented in Table 4.9. Sulphur uptake at harvest was significantly influenced by the RSW application. Significantly highest S uptake (18.82 kg ha^{-1}) was found in raw spentwash at 7.5 lakh liters ha^{-1} followed by raw spentwash at 5.0 lakh liters ha^{-1} (17.91 kg ha^{-1})and T_3 receiving 2.5 lakh liters ha^{-1}(15.03 kg ha^{-1}). Application of gypsum @100% GR recorded lowest S uptake (12.77 kg ha^{-1}) and which was significantly higher (8.84 kg ha^{-1}) than the treatment with Rec.NPK (no amendment).

4.2.2.3.7 Iron

The effect of raw spentwash and gypsum application on iron (Fe) uptake is presented in Table 4.9. Iron uptake at harvest was significantly influenced by the RSW application. Significantly highest Fe uptake (66.79 mg kg^{-1}) was found in raw spentwash at 7.5 lakh liters ha^{-1} followed by RSW at 5.0 lakh liters ha^{-1} (66.62 mg kg^{-1}) and T_3 receiving rawspentwash @ 2.5 lakh liters ha^{-1}. Application of gypsum @100% GR recorded lowest uptake (38.16 mg kg^{-1}) of iron and was significantly higher than the treatment Rec.NPK (no amendment) (12.52 mg kg^{-1}).

4.2.2.3.8 Manganese

The effect of raw spentwash and gypsum application on manganese (Mn) uptake is presented in Table 4.9. Manganese uptake at harvest was significantly influenced by the RSW application. Significantly highest Mn uptake(49.22 mg kg^{-1}) was found in raw spentwash at 7.5 lakh liters ha^{-1}followed by RSW at 5.0 lakh liters ha^{-1} (49.08 mg kg^{-1}) and in T_3 (2.5 lakh liters ha^{-1}). Application of gypsum @100% GR recorded uptake of Mn (25.17 mg kg^{-1}) and which was significantly higher than the treatment with Rec.NPK (no amendment) (11.06 mg kg^{-1}).

4.2.2.3.9 Copper

The effect of raw spentwash and gypsum application on copper (Cu) uptake is presented in Table 4.9. Copper uptake at harvest was significantly influenced by the RSW application. Significantly highest Cu uptake(8.55 mg kg^{-1}) was found in raw spentwash at 7.5 lakh liters ha^{-1} followed by treatment receiving raw spentwash at 5.0 lakh liters ha^{-1} (8.13 mg kg^{-1}) and T_3 (RSW@ 2.5 lakh liters ha^{-1}) . Application of gypsum @100% GR recorded lowest uptake of Cu (6.02 mg kg^{-1}) and which was significantly higher than the treatment Rec.NPK (no amendment).

4.2.2.3.10 Zinc

The effect of raw spentwash and gypsum application on zinc (Zn) uptake is presented in Table 4.9. Zn uptake at harvest was significantly influenced by the RSW application. Significantly highest Zn uptake (5.71 mg kg^{-1}) was found in raw spentwash at 5.0 lakh liters ha^{-1} and T_3 (RSW@ 2.5 lakh liters ha^{-1}). Application of gypsum @100% GR recorded lowest uptake (3.89 mg kg^{-1}) of Zn and was significantly higher than the treatment rec. NPK (no amendment) (1.75 mg kg^{-1}).

4.2.2.4 Chemical properties of soil

4.2.2.4.1 Soil pH

The soil pH differed significantly due to raw spentwash and gypsum application at all stages of crop growth (Table 4.10). The initial pH of the soil which was 9.58 (Table.3) was reduced significantly during the course of reclamation using raw spentwash and gypsum.

At tillering stage the reduction in soil pH was maximum in T_4 (5.0 lakh liters of raw spentwash ha^{-1}) followed by T_5 (RSW@ 7.5 lakh liters ha^{-1}) (9.25) and were significantly superior over treatments involving application of gypsum @ 100% GR (9.35) and T_3 (RSW @2.5 lakh liter ha^{-1}) (9.34) and the effect of both the treatments were on par with each other. Significantly higher pH (9.54) was recorded in T_1 with rec. NPK (no amendment).

At flowering stage, the reduction in soil pH followed a similar trend as at the tillering stage. Application of raw spentwash @ 5.0 lakh liters ha^{-1} (T_4) and T_5 (7.5 lakh liters ha^{-1}) showed significant reduction in soil pH 8.94 and 9.01 respectively, the effect of both the treatments were on par with each other. Significantly higher pH (9.52) was

Table 4.10 : Effect of raw spentwash and gypsum on chemical properties of soil at different stages of paddy at VC farm, Mandya (Field experiment I)

Treatments	pH (1:2)			EC (dS m^{-1})			OC (per cent)		
	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest
T_1	9.54	9.52	9.50	0. 91	0.85	0.86	0.34	0.36	0.37
T_2	9.35	9.25	9.20	1.07	0.90	0.88	0.39	0.40	0.41
T_3	9.34	9.20	9.17	1.65	1.43	1.20	0.75	0.72	0.51
T_4	9.21	8.94	8.92	1.82	1.55	1.39	0.81	0.79	0.57
T_5	9.25	9.01	8.98	2.23	2.08	1.80	0.87	0.864	0.62
SEm±	0.019	0.03	0.019	0.08	0.13	0.06	0.02	0.03	0.04
CD(p=0.05)	0.060	0.11	0.058	0.26	0.41	0.18	0.06	0.10	0.12

T_1: Recommended NPK (without amendment)
T_2: Gypsum @100% GR + Recommended NPK
T_3: Raw Spentwash @ 2.50 lakh liters ha^{-1}
T_4: Raw Spentwash @ 5.0 lakh liters ha^{-1}
T_5: Raw Spentwash @ 7.5 lakh liters ha^{-1}

noticed in T_1 receiving NPK (no amendment) compared to T_2 gypsum @ 100% GR (9.25) and T_3 (RSW 2.5 lakh liter ha^{-1}) (9.20).

After harvest, in general there was no drastic reduction in soil pH compared to other two stages of crop growth. However, reduction in soil pH was lowest in T_4 (raw spentwash @ 5.0 lakh liters ha^{-1}) (8.92) followed by T_5 (raw spentwash @ 7.5 lakh liters ha^{-1}) (8.98) and were significantly superior over control and treatments receiving gypsum.

4.2.2.4.2 Electrical conductivity

The effect of raw spentwash and gypsum application on electrical conductivity (EC) of soil during the course of reclamation are presented in Table 4.10. At tillering stage, accumulation of soluble salts in soil was highly significant with application of raw spentwash compared to gypsum application. The raw spentwash @7.5 lakh liters ha^{-1} (2.23 dS m^{-1}) recorded significantly higher EC values followed by T_4 (RSW @ 5.0 lakh liters ha^{-1}) (1.82 d Sm^{-1}) and T_3 (RSW 2.5 lakh liter ha^{-1}) (1.65 dS m^{-1}) compared to T_2 (gypsum @ 100% GR) (1.07 dS m^{-1}).

At flowering stage, a similar trend was noticed as at tillering stage and significantly highest (2.08 dS m^{-1}) EC was noticed with raw spentwash @ 7.5 lakh liters ha^{-1} followed by T_4 (RSW @ 5.0 lakh liters ha^{-1}) (1.55 dS m^{-1}) and T_3 (RSW 2.5 lakh liter ha^{-1}) (1.43 dS m^{-1}) .While, T_2 and T_1 soil EC did not show significant difference.

At harvest, in general, there was significant reduction in soil EC compared to two other stages of crop but was significantly higher compared to T_1 receiving NPK (no amendment) & T_2(Gypsum @ 100% GR).

4.2.2.4.3 Organic carbon

The organic carbon (OC) content of soil as influenced by raw spentwash and gypsum application is represented in Table 4.10. Increased application of raw spentwash progressively increased the OC content of soil compared to plots receiving gypsum and RDF.

At tillering stage, significantly higher OC (0.87 per cent) was noticed with raw spentwash @ 7.5 lakh liters ha^{-1} followed by T_4 (RSW @ 5.0 lakh liters ha^{-1}) (0.81 per cent) and T_3 (RSW @ 2.5 lakh liter ha^{-1}) (0.75 per cent) respectively compared to T_2 gypsum @ 100% GR and T_1 receiving NPK (no amendment).

Similar trend was observed at flowering stage. Application of raw spentwash @7.5 lakh liters ha^{-1} recorded 0.84 per cent followed by T_4 (RSW @ 5.0 lakh liters ha^{-1}) (0.79 per cent) and T_3 (RSW @ 2.5 lakh liter ha^{-1}) (0.72 per cent) and were on par with each other. The lowest OC (0.36 per cent) was observed with rec. NPK (no amendment).

At harvest, significant accumulation of OC in soil was noticed in all the treatments receiving raw spentwash compared to the initial value 0.34.

4.2.2.4.4 Available Nitrogen

The data pertaining to available N content of soil at all the stages of crop growth as affected by raw spentwash and gypsum application are presented in Table 4.11

At tillering stage, raw spentwash applied treatments recorded higher available N content of soil compared to (T_2) gypsum @ 100% GR and T_1 (rec. NPK (no amendment). The highest available N was noticed with raw spentwash@7.5 lakh liters ha^{-1} (618.22 kg ha^{-1}) followed by raw spentwash @ 5.0 lakh liters ha^{-1} (493.40 kg ha^{-1}), raw spentwash @2.5 lakh liters ha^{-1} (363.74 kg ha^{-1})and was significantly superior over T_2 receiving gypsum @ 100% GR (201.17 kg ha^{-1}) and rec. NPK (no amendment) (198.14 kg ha^{-1}).

At flowering stage, lowest available N was noticed in T_1 receiving only RDF (178.49 kg ha^{-1}), which was significantly lower than all spentwash applied treatments but was on par with T_2 (gypsum 100% GR +Rec.NPK). The raw spentwash @7.5 lakh liters ha^{-1} (552.3 kg ha^{-1}), raw spentwash @ 5.0 lakh liters ha^{-1} (385.34 kg ha^{-1}) and T_3 (276.5 kg ha^{-1}) accumulated significantly higher available N.

At harvest, available N in soil differed significantly due to application of raw spentwash. The raw spentwash@ 7.5 lakh liters ha^{-1} (244.36 kg ha^{-1}) accumulated

Table 4.11 : Effect of application of different quantities of raw spentwash on available N, P, K and S content of soil at different stages of paddy at VC farm, Mandya (Field experiment I)

Treatments	Avail.N (kg ha^{-1})			Avail.P (kg ha^{-1})			Avail.K (kg ha^{-1})			Avail.S (mg kg^{-1})		
	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest
T_1	198.14	178.49	167.52	14.64	12.65	12.17	138.19	128.63	113.06	5.33	5.59	5.43
T_2	201.17	185.35	172.10	16.53	13.29	12.28	175.30	135.40	126.85	6.66	6.78	5.90
T_3	363.74	276.50	205.34	26.46	19.44	15.48	619.96	497.03	352.02	10.58	6.70	6.14
T_4	493.40	385.34	322.98	32.56	24.02	17.71	815.48	763.34	583.51	15.14	10.65	8.98
T_5	618.22	552.30	484.36	50.10	38.21	29.14	950.51	871.85	784.78	20.61	14.57	10.93
SEm±	12.92	9.97	12.82	0.75	1.60	1.92	18.37	19.81	16.25	1.06	0.55	0.71
CD(p=0.05)	39.81	30.73	39.53	2.32	4.94	5.9	56.61	61.06	50.10	3.26	1.69	2.20

T_1: Recommended NPK (without amendment)
T_2: Gypsum @100% GR + Recommended NPK
T_3: Raw Spentwash @ 2.50 lakh liters/ha+ balance of P
T_4: Raw Spentwash @ 5.0 lakh liters/ha + balance of P
T_5: Raw Spentwash @ 7.5 lakh liters/ha + balance of P

significantly higher available N followed by T_4 receiving raw spentwash @ 5.0 lakh liters ha^{-1} (322.98 kg ha^{-1}).

4.2.2.4.5 Available phosphorus

The data on available P content of soil showed significant differences at different stages (Table 4.11). At tillering stage, application of raw spentwash resulted in significant difference in available P content of soil. The application of raw spentwash @ 7.5 lakh liters ha^{-1} recorded significantly higher available P (40.10 kg ha^{-1}) followed by T_4 (38.56 kg ha$^{-1)}$ which received raw spentwash @ 5.0 lakh liters ha^{-1}. The lowest (14.64 kg ha^{-1}) available P was noticed with T_1 receiving NPK (without amendment).

At flowering and harvest stages, available P differed significantly due to raw spentwash application. The highest available P was recorded in T_5 treatment, while lowest was with T_1 during flowering and at harvest.

4.2.2.4.6 Available Potassium

The data pertaining to available K content of soil at different growth stages as influenced by raw spentwash and gypsum application is presented in Table 4.11. Significantly highest available K was recorded with application of 7.5 lakh liters ha^{-1} followed by the application of raw spentwash at 2.5 & 5.0 lakh liters ha^{-1}, which were significantly superior over all other treatments.

At tillering stage, significantly higher available K was found with application of raw spentwash @ 7.5 lakh liters ha^{-1} (950.51 kg ha^{-1}), followed by 5.0 lakh liters ha^{-1} (815.48 kg ha^{-1}) and 2.5 lakh liters ha^{-1} (619.96 kg ha^{-1}) than treatments receiving RDF and gypsum.

At flowering stage, similar trend was noticed, recording significantly higher available K with the application of raw spentwash @ 7.5 lakh liters ha^{-1} (871.85 kg ha^{-1}), followed by 5.0 lakh liters ha^{-1} (763.34 kg ha^{-1}). Significantly lower available K was observed with T_1 receiving only RDF (128.63 kg ha^{-1}).

At harvest, application of raw spentwash @ 7.5 lakh liters ha^{-1} (784.78 kg ha^{-1}) and at 5.0 lakh liters ha^{-1} (583.51 kg ha^{-1}) recorded significantly higher available K in soil over all other treatments. Gypsum @100% GR + Rec.NPK recorded 126.85 kg ha^{-1} of available K and was on par with receiving NPK treatment (without amendment) (113.06 kg ha^{-1}).

4.2.2.4.7 Available Sulphur

The data on available S content of soil as influenced by application of raw spentwash and gypsum is given in Table 4.11. At tillering stage, highest available S was recorded with raw spentwash @ 7.5 lakh liters ha^{-1} (19.61 mg kg^{-1}) and was on par with raw spentwash @ 5.0 lakh liters ha^{-1}.

At flowering stage, highest available S was found with raw spentwash @ 7.5 lakh liters ha^{-1} (14.57 mg kg^{-1}), followed by T_4 which received raw spentwash @ 5.0 lakh liters ha^{-1} (10.65 mg kg^{-1}) and T_3 receiving raw spentwash @ 2.5 lakh liters ha^{-1} (6.70 mg kg^{-1}). The lowest S content was found in T_1 receiving NPK treatment (without amendment) (5.59 available S mg kg^{-1}). At harvest stage, the highest value was recorded with raw spentwash @ 7.5 lakh liters ha^{-1} (10.93 mg kg^{-1}) and the least was with T_1(5.43 mg kg^{-1}).

4.2.2.4.8 Exchangeable Calcium

Application of raw spentwash and gypsum had significant influence on exchangeable Ca content of soil (Table 4.12). At tillering stage, the highest exchangeable Ca was recorded with T_5 (8.96 cmol (p^+) kg^{-1}) and T_4 (8.65 cmol (p^+) kg^{-1}) which received raw spentwash @ 7.5 lakh liters ha^{-1} and raw spentwash @ 5.0 lakh liters ha^{-1} and were found significantly superior over all other treatments. Application of raw spentwash @ 2.5 lakh liters ha^{-1} and gypsum @ 100% GR also accumulated significantly higher exchangeable Ca (7.38 &7.26 cmol (p^+) kg^{-1}) than rec.NPK (without amendment).

Similar trend was noticed during flowering stage but the exchangeable calcium content of soil decreased slightly with the advancement of crop growth. The highest exchangeable Ca content was observed with raw spentwash @ 7.5 lakh liters ha^{-1} (8.75

Table 4.12 : Effect of application of different quantities of raw spentwash on Exchangeable Ca, Mg, Na and ESP of soil at different stages of paddy at VC farm, Mandya (Field experiment I)

Treatments	Exch.Ca (c mol(p^+)kg^{-1})			Exch.Mg (c mol(p^+)kg^{-1})			Exch.Na (c mol(p^+)kg^{-1})			ESP (per cent)		
	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest
T_1	6.30	6.36	6.38	3.31	2.93	2.78	10.88	10.44	10.36	37.22	36.78	36.64
T_2	7.26	7.13	7.06	3.99	3.39	2.89	7.75	7.23	7.12	28.27	27.09	26.89
T_3	7.38	7.25	7.16	4.29	3.59	2.79	7.09	6.93	6.82	27.48	24.80	24.18
T_4	8.65	8.33	8.20	4.28	4.08	3.59	5.62	5.41	4.72	21.27	20.96	20.77
T_5	8.96	8.75	8.55	4.65	4.28	4.09	5.91	5.55	5.03	22.34	21.93	21.66
SEm±	0.39	0.14	0.13	0.14	0.07	0.08	0.07	0.08	0.19	0.39	1.03	1.04
CD(p=0.05)	1.21	0.44	0.42	0. 45	0.23	0.26	0.22	0.24	0.59	1.22	3.18	3.21

T_1: Recommended NPK (without amendment)
T_2: Gypsum @100% GR + Recommended NPK
T_3: Raw Spentwash @ 2.50 lakh liters ha^{-1}
T_4: Raw Spentwash @ 5.0 lakh liters ha^{-1}
T_5: Raw Spentwash @ 7.5 lakh liters ha^{-1}

cmol (p^+) kg^{-1}), which was on par with raw spentwash @ 5.0 lakh liters ha^{-1} (8.20 cmol (p^+) kg^{-1}). Whereas, lowest calcium content (6.38 cmol (p^+) kg^{-1}) was recorded in T_1 which received rec.NPK (without amendment).

At harvest, the exchangeable Ca content of soil did not vary significantly compared to other two stages. The exchangeable Ca content of soil ranged from 6.38 to 8.55 cmol (p^+) kg^{-1} in T_1 receiving recorded rec.NPK (without amendment) and T_5 receiving raw spentwash @ 7.5 lakh liters ha^{-1}.

4.2.2.4.9 Exchangeable Magnesium

The exchangeable magnesium content of soil was significantly influenced by application of raw spentwash and gypsum (Table 4.12). At tillering stage, raw spentwash @ 7.5 lakh liters ha^{-1} recorded significantly higher exchangeable Mg (4.65 cmol (p^+) kg^{-1}) in soil and was found on par with raw spentwash @ 5.0 lakh liters ha^{-1} (4.28 cmol (p^+) kg^{-1}). While, application of raw spentwash @ 2.5 lakh liters ha^{-1} slightly increased the exchangeable Mg but was on par with T_2 (3.99 cmol (p^+) kg^{-1}) which received gypsum @ 100% GR+Rec.NPK

At flowering stage, application of raw spentwash @ 7.5 lakh liters ha^{-1} recorded significantly higher exchangeable Mg (4.28 cmol (p^+) kg^{-1}) in soil compared to other treatments. The application of raw spentwash @ 5.0 lakh liters ha^{-1} recorded exchangeable Mg values (4.08 cmol (p^+) kg^{-1}) and was on par with raw spentwash @ 2.5 lakh liters ha^{-1} and gypsum @ 100%GR (3.59, 3.39 cmol (p^+) kg^{-1}) respectively, but was significantly superior over T_1 (2.93 cmol (p^+) kg^{-1}), which received only fertilizers.

The exchangeable Mg content of soil at harvest did not vary significantly compared to other two stages. Relatively higher exchangeable Mg was found with the application of raw spentwash @ 7.5 lakh liters ha^{-1} (4.09 cmol (p^+) kg^{-1}) while lowest (2.78 cmol (p^+) kg^{-1}) was recorded with rec.NPK (without amendment).

4.2.2.4.10 Exchangeable Sodium

The exchangeable sodium content of soil at different stages of crop growth was significantly influenced by application of raw spentwash and gypsum (Table 4.12). At tillering stage, treatment T_1 (Rec.NPK without amendment) recorded significantly highest (10.88 cmol (p^+) kg^{-1}) exchangeable Na and lowest was with raw spentwash @ 5.0 lakh liters ha^{-1} (5.62 cmol (p^+) kg^{-1}). While, application of raw spentwash @ 2.5 lakh liters ha^{-1} recorded 7.09 cmol (p^+) kg^{-1} but was found on par with T_2 (7.75 cmol (p^+) kg^{-1}) which received gypsum @ 100%GR+Rec.NPK

A similar trend was observed at flowering stage. Application of raw spentwash @ 5.0 lakh liters ha^{-1} recorded significantly lower exchangeable Na (5.41 cmol (p^+) kg^{-1}) compared to other treatments. Application of raw spentwash @ 7.5 lakh liters ha^{-1} recorded exchangeable Na (5.55 cmol (p^+) kg^{-1}) and was on par with raw spentwash @ 2.5 lakh liters ha^{-1} (6.93 cmol (p^+) kg^{-1}) and gypsum @ 100% GR (7.23 cmol (p^+) kg^{-1}) respectively, but was significantly superior over T_1 (10.44 c mol (p^+) kg^{-1}) which received rec.NPK without amendment.

The exchangeable Na content of soil at harvest did not show significant differences. However, relatively lowest exchangeable Na was found with the application of raw spentwash @ 5.0 lakh liters ha^{-1} (4.72 cmol (p^+) kg^{-1}), while highest (10.36 cmol (p^+) kg^{-1}) was recorded with rec.NPK (without amendment).

4.2.2.4.11 Exchangeable Sodium Percentage

The data on exchangeable sodium percentage of soil as influenced by application of raw spentwash and gypsum is presented in (Table 4.12). At tillering stage, significantly lowest exchangeable sodium percentage was recorded in T_4 which received raw spentwash @ 5.0 lakh liters ha^{-1} (21.27 per cent) followed by T_5 raw spentwash @ 7.5 lakh liters ha^{-1} (22.34 per cent) and was significantly superior over T_1 (rec.NPK without amendment) which recorded significantly highest exchangeable sodium percentage (37.22 per cent). While, application of raw spentwash @ 2.5 lakh liters ha^{-1} recorded exchangeable sodium percentage of 27.48 per cent which was on par with T_2 (28.27 per cent) which received gypsum @ 100%GR+Rec.NPK

At flowering stage, application of raw spentwash @ 5.0 lakh liters ha^{-1} recorded significantly lowest exchangeable sodium percentage (20.96 per cent) followed by T_5

receiving of raw spentwash @ 7.5 lakh liters ha^{-1} (21.93 per cent). Application of gypsum @ 100% GR recorded a higher exchangeable sodium percentage of 27.09 per cent and was on par with raw spentwash @ 2.5 lakh liters ha^{-1} respectively (24.80 per cent) but was significantly superior over T_1 (36.78 per cent).

At harvest stage, exchangeable sodium percentage did not show any significant difference in soil compared to other two stages. However, relatively lowest exchangeable sodium percentage was found with the application of raw spentwash @ 5.0 lakh liters ha^{-1} (20.77 per cent), while highest (36.64 per cent) was recorded with rec.NPK (without amendment).

4.2.2.4.12 Water soluble cations

4.2.2.4.12.1 Calcium+Magnesium

Application of raw spentwash had significant influence in water soluble Ca+Mg content of soil (Table 4.13).

At tillering stage, the highest Ca+Mg was recorded with T_5 (2.03 meq L^{-1}) and T_4 (1.85 meq L^{-1}) which received application of @ 7.5 lakh liters ha^{-1} and raw spentwash @ 5.0 lakh liters ha^{-1} and were found significantly superior over all other treatments. Application of raw spentwash @ 2.5 lakh liters ha^{-1} and gypsum @ 100% GR also accumulated significantly highest (1.43 and 1.40 meq L^{-1}) Ca+Mg over T_1 rec.NPK (without amendment).

Similar trend was noticed during flowering stage, but the Ca+Mg content of soil decreased slightly with the advancement of crop growth. Highest Ca+Mg was observed with raw spentwash @ 7.5 lakh liters ha^{-1} (1.35 meq L^{-1}), which was on par with raw spentwash @ 5.0 lakh liters ha^{-1} (1.14 meq L^{-1}). Whereas lowest (0.64 meq L^{-1}) Ca+Mg content was recorded in T_1 (rec.NPK (without amendment).

At harvest, the increase in Ca+Mg content of soil due to application of raw spentwash was not significant. Ca+Mg content of soil ranged from 6.38 (T_1) to 8.55 (T_5) cmol (p^+) kg^{-1}.

Table 4.13 : Effect of application of different quantities of raw spent wash on water soluble Ca+ Mg, Na and K content of soil at different stages of paddy at VC farm, Mandya (Field experiment I)

Treatments	Ca+Mg (meq L^{1})			Na (meq L^{-1})			K(meq L^{-1})		
	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest
T_1	0.93	0.64	0.67	16.21	16.17	15.76	0.28	0.24	0.23
T_2	1.40	0.88	0.86	15.34	15.30	11.56	0.47	0.52	0.46
T_3	1.43	0.92	0.89	14.95	14.91	11.15	1.04	0.66	0.61
T_4	1.85	1.14	1.04	12.20	12.15	10.02	1.30	0.96	0.88
T_5	2.03	1.35	1.30	14.21	13.16	13.04	1.40	1.30	1.02
SEm±	0.07	0.08	0.09	0.02	0.73	1.01	0.002	0.10	0.07
CD(p=0.05)	0.22	0.26	NS	0.06	2.26	3.12	0.008	0.33	0.22

T_1: Recommended NPK (without amendment)
T_2: Gypsum @100% GR + Recommended NPK
T_3: Raw Spentwash @ 2.50 lakh liters ha^{-1}
T_4: Raw Spentwash @ 5.0 lakh liters ha^{-1}
T_5: Raw Spentwash @ 7.5 lakh liters ha^{-1}

4.2.2.4.12.2 Sodium and Potassium

Application of raw spentwash and gypsum had significant influence on water soluble sodium content of soil (Table 4.13). At tillering stage, highest sodium content was recorded in T_1 (16.21 meq L^{-1}) followed by treatments receiving gypsum @100% GR+Rec.NPK(T_2) (15.34 meq L^{-1}) ,T_3 receiving raw spentwash @2.5 lakh liters ha^{-1} (14.95 meq L^{-1}), T_5 receiving raw spentwash @7.5 lakh liters ha^{-1} (14.21 meq L^{-1}). Significantly lowest value was recorded in T_4 (12.20 meq L^{-1}). Similar trend was followed in flowering and harvest stage and there was gradual reduction in sodium content when compared to tillering stage.

Similarly, application of raw spentwash had significant influence on water soluble potassium content of soil (Table 4.13). At tillering stage, highest potassium content was recorded in T_5 (1.40 meq L^{-1}) receiving raw spentwash @7.5 lakh liters ha^{-1}followed by treatments receiving T_4 (1.30 meq L^{-1}) and T_3 (1.04 meq L^{-1}) receiving raw spentwash @ 5.0 and 2.5 lakh liters ha^{-1} respectively. (15.34 meq L^{-1}). Significantly lowest value was recorded in T_1(0.28 meq L^{-1}) and T_2 which received gypsum @100% GR+Rec.NPK () (0.47 meq L^{-1}). Similar trend was followed in flowering and harvest stage and there was gradual reduction in potassium content when compared to tillering stage.

4.2.2.4.12.3 DTPA Extractable Iron

The DTPA-Fe was significantly influenced by the application of raw spentwash and gypsum to sodic soil (Table 4.14).

At tillering stage, significantly higher DTPA-Fe was noticed with the application of raw spentwash @ 7.5 lakh liters ha^{-1} (43.50 mg kg^{-1}). Application of raw spentwash @ 5.0 lakh liters ha^{-1} recorded DTPA-Fe value of 37.24 mg kg^{-1} and was on par with the application of raw spentwash @ 2.5 lakh liters ha^{-1} (35.55 mg kg^{-1}).

At flowering stage, a similar trend was observed showing significantly higher DTPA-Fe with the application of raw spentwash @ 7.5 lakh liters ha^{-1} (39.53 mg kg^{-1}) followed by application of raw spentwash @ 5.0 lakh liters ha^{-1} (34.12 mg kg^{-1}). Application of raw spentwash @ 2.5 lakh liters ha^{-1} and gypsum @ 100% GR were found

Table 4.14 : Effect of application of different quantities of raw spentwash on micro nutrients content of soil at different stages of paddy at VC farm, Mandya (Field experiment I).

Treatments	Fe (mg kg^{-1})			Mn (mg kg^{-1})			Zn (mg kg^{-1})			Cu(mg kg^{-1})		
	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest	Tillering stage	Flowering Stage	After harvest
T_1	31.53	31.98	28.04	7.41	6.20	6.17	0.79	0.62	0.60	2.13	2.07	2.03
T_2	34.81	33.17	31.63	7.69	6.59	6.33	0.82	0.68	0.64	2.35	2.21	2.12
T_3	42.55	39.63	32.90	8.15	6.74	6.63	0.89	0.70	0.66	4.14	3.83	3.29
T_4	57.24	48.12	43.59	12.50	8.76	7.39	0.96	0.76	0.68	5.52	4.25	3.83
T_5	63.50	55.53	49.03	15.85	10.24	9.10	1.03	0.86	0.72	7.14	6.55	5.61
SEm±	1.76	1.97	1.81	0.41	0.73	0.55	0.06	0.05	0.07	0.59	0.44	0.36
CD(p=0.05)	5.43	6.07	5.59	1.27	2.26	1.69	NS	NS	NS	1.83	1.34	1.12

T_1: Recommended NPK (without amendment)
T_2: Gypsum @100% GR + Recommended NPK
T_3: Raw Spentwash @ 2.50 lakh liters/ha+ balance of P
T_4: Raw Spentwash @ 5.0 lakh liters/ha + balance of P
T_5: Raw Spentwash @ 7.5 lakh liters/ha + balance of P

to be on par (51.81 and 49.16 mg kg^{-1}) and were superior over rec. NPK (without amendment).

At harvest, application of raw spentwash @ 7.5 lakh liters ha^{-1} (35.03 mg kg^{-1}) brought significant increase in DTPA-Fe content of soil compared to T_1 receiving rec. NPK (without amendment) (28.04 mg kg^{-1}) and was found on par with all other treatments.

4.2.2.4.12.4 DTPA Extractable Manganese

The data on DTPA extractable-manganese content of soil as influenced by the application of raw spentwash and gypsum at all growth stages is presented in Table 4.14. Significantly highest DTPA- Mn (15.85 mg kg^{-1}) was recorded in T_5 which received 7.5 lakh liters ha^{-1} followed by T_4 (12.50 mg kg^{-1}) and T_3 (8.15 mg kg^{-1}) which received 5.0 lakh liters ha^{-1} and 2.5 lakh liters ha^{-1}. Significantly lowest DTPA- Mn (7.41 mg kg^{-1}) was recorded in T_1 (Rec.NPK +without amendment). Similar trend was found at flowering and harvest stages also.

4.2.2.4.12.5 DTPA Extractable Copper

The application of raw spentwash and gypsum to sodic soil resulted in significant difference in DTPA- Cu content of soil only at tillering stage (Table 4.14). Significantly highest DTPA- Cu was recorded in T_5 which received 7.5 lakh liters ha^{-1} and was on par with T_4 (3.52 mg kg^{-1}) and T_3 (3.14 mg kg^{-1}) which received rawspentwash @ 5.0 lakh liters ha^{-1} and 2.5 lakh liters ha^{-1}. Significantly lowest DTPA- Cu (2.13 mg kg^{-1}) was recorded in T_1 (rec.NPK +without amendment).

At flowering and at harvest, application of raw spentwash @ 7.5 lakh liters ha^{-1} recorded highest DTPA- Cu (3.61 mg kg^{-1}) in soil and lowest was in T_1 (2.03 mg kg^{-1}) which received only chemical fertilizers.

4.2.2.4.12.6 DTPA Extractable Zinc

The data on DTPA extractable Zn as influenced by the application of raw spentwash and gypsum to sodic soil is presented in Table 4.14. The influence of raw spentwash application was not significant in increasing the DTPA- Zn content of soil at any stage of crop growth. However, raw spentwash @ 7.5 lakh liters $ha^{-1}$and T_4 (5.0 lakh liters ha^{-1}) maintained relatively higher DTPA- Zn values (0.72 mg kg^{-1}) and (0.76 mg kg^{-1}) respectively at all stages of crop growth.

4.2.2.5 Effect of different quantities of spentwash application on chemical composition of leachate collected in piezometers in field experiment -I

The data pertaining to the chemical composition of spentwash collected at 0.5 m depth after 30, 60 and 90 days of raw spentwash application is presented in Table 4.15.

In general, pH, EC, HCO_3^-, Cl^- , SO_4^{2-} and Na^+ increased with percolating water collected at 0.5 meter depth, which may be due to leaching. Among cations, sodium leached more compared to calcium and magnesium. Increasing the quantity of RSW application increased the soluble salts, cations and anions in percolating water compared to the treatments receiving gypsum and Rec.NPK.

The data indicated that with increase in the quantity of RSW application the pH, EC, HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+} and Na^+, values ranged from 7.23 to 9.04, 0.79 to 8.91 (dS m^{-1}), 1.38-16.86 (meq L^{-1}), 2.37 to 6.20 (meq L^{-1}), 2.36 to 5.95 (meq L^{-1}), 1.50 to 7.48 (meq L^{-1}) and 0.3 to 2.41 (meq L^{-1}) in the leachate collected at 0.5m depth.

After 30 days of application of RSW and gypsum, significantly highest value with respect to pH EC, HCO_3^-, Cl^-, SO_4^{2-} , Ca^{2+}, Mg^{2+} and Na^+, were recorded in T_5 which received raw spentwash @ 7.5 lakh liters ha^{-1} followed by T_4 and T_3 compared to gypsum and control plots. Among the cations, the quantity of sodium leached was more compared to Ca and Mg. Among the anions, the order was $HCO_3^- > Cl^- > SO_4^{2-}$. After 60 days and 90 days after transplanting, the content of soluble salts and cations and anions decreased in the leachate collected in piezometers.

Table 4.15 : Effect of application of different quantities of raw spentwash on chemical composition of leachate collected from piezometers installed in the field experiment-I

Piezometer	pH	EC (dS m^{-1})	Ca meq L^{1}	Mg meq L^{-1}	Na meq L^{-1}	K meq L^{-1}	Chlorides meq L^{-1}	Bicarbonates meq L^{1}	Sulphates meq L^{-1}
30 days after spentwash application									
T_1	7.48	0.86	1.50	0.30	1.13	0.13	2.45	2.29	2.66
T_2	7.99	1.02	2.49	0.80	3.83	0.21	2.51	2.57	2.76
T_3	8.36	3.57	4.99	1.94	8.86	0.46	3.61	9.85	3.27
T_4	8.89	5.44	5.99	2.24	9.62	0.54	4.04	12.66	4.28
T_5	9.04	8.91	7.48	2.41	12.68	0.83	6.20	16.86	5.95
SEm±	0.36	0.57	0.93	0.11	1.17	0.10	0.10	1.33	0.56
CD (5%)	1.11	1.77	2.87	0.35	3.61	0.31	0.32	4.11	1.73
60 days after spentwash application									
T_1	7.40	0.79	1.00	0.40	1.28	0.08	2.45	1.52	2.43
T_2	7.93	0.96	2.00	0.60	3.41	0.19	2.92	1.58	2.51
T_3	8.30	2.63	2.98	1.04	8.00	0.36	3.12	6.54	2.42
T_4	8.64	3.21	4.48	1.39	8.38	0.37	3.93	7.67	3.41
T_5	8.90	6.48	5.78	1.88	11.64	0.54	4.67	10.39	4.77
SEm±	0.50	0.53	0.36	0.10	0.73	0.08	0.37	0.91	0.44
CD (5%)	1.55	1.63	1.12	0.31	2.25	0.25	1.14	2.81	1.37
90 days after spentwash application									
T_1	7.26	0.84	1.00	0.40	1.06	0.07	2.37	1.38	2.36
T_2	7.23	1.02	2.00	0.55	2.85	0.15	2.87	1.46	2.55
T_3	7.41	2.57	3.74	1.04	7.68	0.18	2.83	3.53	2.14
T_4	7.49	3.04	3.66	1.34	8.24	0.27	3.05	4.11	3.34
T_5	7.76	4.21	4.76	1.65	9.63	0.30	3.96	6.92	3.40
SEm±	0.07	0.22	0.50	0.09	0.37	0.06	0.07	0.36	0.18
CD (5%)	0.23	0.69	1.56	0.30	1.15	0.19	0.22	1.12	0.58

T_1: Recommended NPK (without amendment), T_2: Gypsum @100% GR + Recommended NPK ,T_3: Raw Spentwash @ 2.50 lakh liters ha^{-1}
T_4: Raw Spentwash @ 5.0 lakh liters ha^{-1} T_5: Raw Spentwash @ 7.5 lakh liters ha^{-1}

4.3 Ferti-irrigation studies in paddy

4.3.1 Green House experiment II: Effect of ferti-irrigation of spentwash on growth & yield of paddy

4.3.1.1 Growth parameters

4.3.1.1.1 Plant height

The relevant data pertaining to plant height, number of productive tillers, number of panicles, number of seeds panicles^{-1}, grain yield and straw yield are presented in the Table 4.16.

The plant height of paddy differed significantly due to ferti-irrigation of distillery spentwash (DSW). Significantly highest plant height (76.04 cm) was observed in T_{14} (150% RDN through distillery spentwash in (33.3%) in each irrigation) followed by, T_{11} (150% RDN through urea (50%) in each irrigation) (75.51cm) and T_9 (75.32cm). Significantly lowest (67.43cm) plant height was recorded in T_4 (100%RDN through urea 20% in each irrigation) and it was on par with 150% RDN through urea (20% in each irrigation) (68.14cm).

4.3.1.1.2 Number of tillers

The data pertaining to ferti-irrigation of distillery spentwash on number of tillers is presented in Table. 4.16. Significantly highest number of tillers was recorded in T_{15} (23.14) followed by T_{14} (22.95), T_{13} (22.75) and T_8 (22.62) and T_1 (22.85) which received150%RDN through DSW (50% in each irrigation), 150%RDN through DSW (33.3% in each irrigation), 150%RDN through DSW (20% in each irrigation), 150%RDN through urea (33.3% in each irrigation) and RDF (NPK) +FYM respectively.

Significantly lower (19.12) number of tillers was recorded in T_2 (100% RDN through distillery spentwash 20% in 6 irrigations).

Table 4.16 : Effect of ferti- irrigation of primary spentwash on growth & yield (g pot^{-1}) of paddy

Parameters	Plant height cm	No.of tillers	No.of seeds / panicle	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
T_1: RDF (NPK) +FYM	74.83	22.85	124.3	24.82	33.85
T_2: 100% RDN through DSW (in 6 irrigations) +balance of P	71.83	19.12	118.8	20.43	28.53
T_3: 150% RDN through DSW (in 6 irrigations) +balance of P	74.03	19.95	121.3	23.30	31.88
T_4: 100%RDN through urea (20% in each irrigation) + RDP &RDK	67.43	19.45	118.6	21.04	27.29
T_5: 100%RDN through urea (33.3% in each irrigation)+ RDP &RDK	70.00	19.95	123.1	22.86	29.07
T_6: 100%RDN through urea (50% in each irrigation)+ RDP&RDK	70.46	19.95	122.1	22.23	29.07
T_7: 150%RDN through urea (20% in each irrigation)+ RDP &RDK	68.14	21.45	123.6	23.34	32.31
T_8: 150%RDN through urea (33.3% in each irrigation)+ RDP &RDK	73.66	22.62	123.1	24.16	34.21
T_9: 150%RDN through urea (50% in each irrigation)+ RDP&RDK	75.32	21.75	122.5	23.50	33.67
T_{10}: 100%RDN through DSW (20% in each irrigation)+ balance of P	71.83	20.93	122.4	22.49	30.79
T_{11}: 100%RDN through DSW (33.3% in each irrigation)+ balance of P	75.51	21.15	122.8	23.90	32.43
T_{12}: 100%RDN through DSW (50% in each irrigation) + balance of P	74.83	21.45	123.5	23.59	31.86
T_{13}: 150%RDN through DSW (20% in each irrigation)+ balance of P	73.26	22.75	121.7	23.77	34.07
T_{14}: 150%RDN through DSW (33.3% in each irrigation)+ balance of P	76.04	22.95	126.4	25.80	36.09
T_{15}: 150%RDN through DSW (50% in each irrigation)+ balance of P	74.03	23.14	125.2	24.99	34.40
SEm±	1.31	0.98	1.15	0.44	1.22
CD (5%)	3.82	2.86	3.34	1.28	3.55

4.3.1.1.3 Number of seeds per panicle

The data pertaining to ferti-irrigation of primary spentwash on number of seeds per panicle is presented in Table.4.16. Ferti-irrigation of spentwash significantly influenced the number of filled grains per panicle. Highest number of seeds per panicle was recorded in T_{14} treatment (126.4) which received 150% RDN through distillery spentwash (33% in each irrigation) followed by T_{15} (150% RDN through distillery spentwash 50% in each irrigation) (125.2) and was on par with T_1 (NPK+FYM) (124.3). Significantly lowest (118.6) number of panicles were recorded in treatment receiving 100% RDN through urea (20% in each irrigation) and was on par with treatment T_2 (100% RDN through distillery spentwash in 6 irrigations) (118.8).

4.3.1.2 Yield

4.3.1.2.1 Grain yield

The data pertaining to ferti-irrigation of distillery spentwash on grain yield of paddy is presented in Table.4.16. Application of distillery spentwash @150% RDN (33% in each irrigation) recorded highest yield of 25.80 g pot^{-1} followed by 150% N through urea in (50% in each irrigation) (24.99 g pot^{-1}), while RDF (NPK) + FYM recorded grain yield of 24.82 (g pot^{-1}). Application of 150% RDN through urea (33% in each irrigation) recorded (24.16 g pot^{-1}) which was on par with 100% RDN through distillery spentwash (33% in each irrigation) (23.90 g pot^{-1}), T_{13} (23.77 g pot^{-1}), T_{12} (23.59 g pot^{-1}),T_9 (23.50 g pot^{-1}).Significantly lowest grain yield was recorded in T_2 (20.43 g pot^{-1}) followed by 100% RDN through urea (20% in each irrigation) 21.04 g pot^{-1}.

4.3.1.2.2 Straw yield

The data pertaining to ferti-irrigation of distillery spentwash on straw yield of paddy is presented in Table 4.16. Significantly highest straw yield was recorded in T_{14} (36.09 g pot^{-1}) treatment which received 150% RDN through distillery spentwash in 3 irrigations followed by T_{15} (34.40 g pot^{-1}) and T_8 and T_{13} which recorded 34.21 g pot^{-1} and 34.07 g pot^{-1} respectively.

Application of RDF+FYM recorded 33.85 g pot^{-1} which was on par with150% RDN through distillery spentwash in 6 irrigation (31.88 g pot^{-1}), followed by T_7 which received 150% RDN through urea (20% in each irrigation) (32.31 g pot^{-1}), 100% RDN through distillery spentwash (33% in each irrigation) and 100% RDN through distillery spentwash (50% in each irrigation) recorded 32.43 & 31.86 g pot^{-1} respectively.

Significantly lowest (27.29 g pot^{-1}) yield was recorded in 100% RDN through urea (20% in each irrigation) and was on par with 150% RDN through distillery spentwash (6 irrigation) followed 100% RDN (33 & 50% in each irrigation) (29.07 g pot^{-1}).

4.3.1.3 Uptake

4.3.1.3.1 Nitrogen uptake

The effect of ferti-irrigation of distillery spentwash on N- uptake by paddy is presented in Table.4.17. Application of 150% RDN through distillery spentwash (33% in each irrigation) recorded significantly higher value (86.64 mg pot^{-1}) and was on par with T_{15} (84.16 mg pot^{-1}) which received 150%RDN through DSW (50% in each irrigation). Fert-irrigation with 150% RDN through urea (33% in each irrigation) recorded highest value of 82.42 mg pot^{-1} among chemical fertilizer applied treatments and was on par with 150% RDN through distillery spentwash (20 % in each irrigation), RDF+FYM and 150% RDN through urea in (50% in each irrigation) which recorded 80.52 mg pot^{-1}, 80.28 mg pot^{-1}, 79.57 mg pot^{-1} respectively. Significantly the lowest (69.12 mg pot^{-1}) N uptake was recorded in which received 100% RDN through urea (20% in each irrigation) followed by 100% RDN through distillery spentwash in 6 irrigations (69.19 mg pot^{-1}).

4.3.1.3.2 P-uptake

The data pertaining to ferti-irrigation of distillery spentwash on P-uptake (mg pot^{-1}) is presented in Table.4.17. Significantly highest P uptake was recorded in T_{14} receiving 150% RDN through DSW (33.3% in each irrigation) (50.19 mg pot^{-1}) followed by T_{15}

Table 4.17 : Effect of ferti-irrigation of primary spentwash on Nitrogen, Phosphorus, Potassium, Suhphur uptake (mg pot^{-1}) by paddy

Parameters	N	P	K	S
T_1: RDF (NPK) +FYM	80.28	46.36	70.57	9.31
T_2: 100% RDN through DSW (in 6 irrigations) +balance of P	69.19	37.12	72.84	9.28
T_3: 150% RDN through DSW (in 6 irrigations) +balance of P	73.72	43.79	78.44	9.39
T_4: 100%RDN through urea (20% in each irrigation) + RDP &RDK	69.12	40.61	67.37	8.27
T_5: 100%RDN through urea (33.3% in each irrigation)+ RDP &RDK	71.49	42.96	68.24	8.32
T_6: 100%RDN through urea (50% in each irrigation)+ RDP&RDK	71.65	40.94	66.81	8.28
T_7: 150%RDN through urea (20% in each irrigation)+ RDP &RDK	75.24	44.89	67.79	9.63
T_8: 150%RDN through urea (33.3% in each irrigation)+ RDP &RDK	82.42	46.65	69.26	9.73
T_9: 150%RDN through urea (50% in each irrigation)+ RDP&RDK	79.57	44.84	68.37	9.51
T_{10}: 100%RDN through DSW (20% in each irrigation)+ balance of P	71.45	41.20	73.63	10.35
T_{11}: 100%RDN through DSW (33.3% in each irrigation)+ balance of P	76.73	45.26	75.56	11.04
T_{12}: 100%RDN through DSW (50% in each irrigation) + balance of P	76.59	44.00	74.36	10.50
T_{13}: 150%RDN through DSW (20% in each irrigation)+ balance of P	80.52	45.67	74.29	10.77
T_{14}: 150%RDN through DSW (33.3% in each irrigation)+ balance of P	86.64	50.19	78.66	11.55
T_{15}: 150%RDN through DSW (50% in each irrigation)+ balance of P	84.16	48.38	75.57	11.60
SEm±	1.39	1.18	0.92	0.45
CD (5%)	4.04	3.44	2.67	1.30

which received 150% RDN through DSW (50% in each irrigation) (48.38 mg pot^{-1}) and (46.36 mg pot^{-1}) (T_1) RDF+FYM respectively.

Among the distillery spentwash treatments, application of 150% RDN through distillery spentwash (20% in each irrigation) (45.67 mg pot^{-1}) recorded highest value and was significantly superior over 150% RDN through urea (50% in each irrigation) 44.84 mg pot^{-1} followed by 100% RDN through urea 33% in each irrigation recorded 42.96 mg $pot^{-1}$and was on par with 100% RDN through distillery spentwash (33% in each irrigation) recorded highest value 45.26 mg pot^{-1}.

4.3.1.3.3 K uptake

The data pertaining to ferti irrigation of spentwash on potassium uptake (g pot^{-1}) by paddy crop is presented in Table (4.17). Ferti-irrigation with 150% RDN through distillery spentwash (3 irrigation) recorded significantly higher value (78.66 mg pot^{-1}) and was on par with, T_3 (78.44 mg pot^{-1}), T_{15} (75.57 mg pot^{-1}). 100% RDN through distillery spentwash recorded significantly higher value (75.56 mg pot^{-1}) compared to RDF+FYM (70.57 mg pot^{-1}), 150% RDN through urea (33% in each irrigation) (69.26 mg pot^{-1}), 150% RDN through urea in (50% in each irrigation) (68.37 mg pot^{-1}) and 100% RDN through urea (33% in each irrigation) (68.24 mg pot^{-1}). Significantly lowest (66.81 mg pot^{-1}) K uptake was recorded in 100% RDN through urea(50% in each irrigation).

4.3.1.3.4 S uptake

The effect of ferti-irrigation of spent wash on uptake pf sulphur by paddy crop is presented in Table 4.17. Application of 150% RDN through distillery spentwash (50% in each irrigation) recorded significantly higher value (11.60 mg pot^{-1}) followed by T_{14} (11.55 mg pot^{-1}), T_{11} (11.04 mg pot^{-1}), T_{13} (10.77 mg pot^{-1}), T_{12} (10.50 mg pot^{-1}) and was significantly superior over 100%, 150% RDN through Urea and RDF+FYM. Significantly lowest S uptake was recorded in (8.27 mg pot^{-1}) which received 100% RDN through urea (20% in each irrigation).

4.3.1.4 Chemical properties of soil

4.3.1.4.1 Soil pH

The data pertaining to the effect of ferti-irrigation of spentwash on soil after the harvest of paddy crop is given in Table. 4.18. Significantly higher pH values were recorded due to ferti-irrigation of distillery spentwash when compared to chemical fertilizers and RDF+FYM treatment. Significantly higher soil pH (7.42) was noticed in T_{15} (150% RDN through distillery spentwash (50% in each irrigation) and was on par with other distillery spentwash applied treatments. While in treatments involving chemical fertilizers, treatment T_7 receiving 150% RDN through urea (20% in each irrigation) recorded higher pH value of 7.26 followed by T_8 (150% RDN through distillery spentwash + 50% in each irrigation) and T_9 receiving 150% RDN through urea (50% in each irrigation) and these treatments recorded pH values 7.25, 7.24 respectively. Significantly lowest (7.19) pH value was recorded in T_5 (100% RDN through urea (33.3% in each irrigation).

4.3.1.4.2 Electrical conductivity

The data on electrical conductivity (EC) of soil as influenced by ferti-irrigation of distillery spentwash is presented in Table 4.18. Significantly higher EC (0.32 dS m^{-1}) was noticed with distillery spentwash ferti-irrigation at 150 per cent RDN through distillery spentwash (33% in each irrigation), T_{13} (0.31 dS m^{-1}) and T_{15}which received 150 per cent RDN through distillery spentwash (50% in each irrigation) recorded 0.30 dS m^{-1}. While, all other treatments did not show significant difference. Accumulation of soluble salts in soil was not significant. The EC of soil ranged from 0.16 to 0.32 dS m^{-1} with highest value being recorded by treatment involving distillery spentwash ferti-irrigation at 150 per cent RDN and lowest by RDF+ FYM (T_1) treatment.

4.3.1.4.3 Organic carbon

The data on Organic carbon (OC) of soil as influenced by ferti-irrigation of distillery spentwash is presented in Table 4.18. Significantly higher OC content (0.74 per cent) was noticed with ferti-irrigation at 150 per cent RDN through distillery spentwash

Table 4.18 : Effect of ferti-irrigation of primary spentwash on chemical properties of soil after harvest of paddy

Parameters	pH (1:2.5)	EC dS m^{-1}	OC (per cent)
T_1: RDF (NPK) +FYM	7.26	0.16	0.66
T_2: 100% RDN through DSW (in 6 irrigations) +balance of P	7.35	0.23	0.68
T_3: 150% RDN through DSW (in 6 irrigations) +balance of P	7.40	0.32	0.71
T_4: 100%RDN through urea (20% in each irrigation) + RDP &RDK	7.25	0.18	0.48
T_5: 100%RDN through urea (33.3% in each irrigation)+ RDP &RDK	7.19	0.19	0.47
T_6: 100%RDN through urea (50% in each irrigation)+ RDP&RDK	7.23	0.17	0.47
T_7: 150%RDN through urea (20% in each irrigation)+ RDP &RDK	7.26	0.18	0.46
T_8: 150%RDN through urea (33.3% in each irrigation)+ RDP &RDK	7.25	0.17	0.47
T_9: 150%RDN through urea (50% in each irrigation)+ RDP&RDK	7.24	0.19	0.45
T_{10}: 100%RDN through DSW (20% in each irrigation)+ balance of P	7.34	0.24	0.66
T_{11}: 100%RDN through DSW (33.3% in each irrigation)+ balance of P	7.37	0.27	0.67
T_{12}: 100%RDN through DSW (50% in each irrigation) + balance of P	7.39	0.29	0.68
T_{13}: 150%RDN through DSW (20% in each irrigation)+ balance of P	7.40	0.31	0.70
T_{14}: 150%RDN through DSW (33.3% in each irrigation)+ balance of P	7.41	0.32	0.74
T_{15}: 150%RDN through DSW (50% in each irrigation)+ balance of P	7.42	0.30	0.73
SEm±	0.035	0.011	0.03
CD (5%)	0.105	0.032	0.09

(33% in each irrigation) and was on par with 100% RDN through distillery spentwash (50% in each irrigation) and T_1(RDF+NPK) recorded 0.68per cent, 0.66 per cent respectively. While, all other treatments which received chemical fertilizers did not record significant differences.

4.3.1.4.4 Available Nitrogen

The data on available nitrogen (N) content of soil as influenced by ferti-irrigation of distillery spentwash is presented in Table 4.19. Significantly higher available nitrogen (326.8 kg ha^{-1}) was recorded in treatment T_7 150%RDN through urea (20% in each irrigation) followed by T_9 (150% RDN through urea 50% in each irrigation) (325.6 kg ha^{-1}) and T_{14} which received ferti-irrigation of spentwash at 150 per cent RDN through distillery spentwash (33% in each irrigation) recorded 324.8 kg ha^{-1}. Significantly lowest value (299.3 kg ha^{-1}) was recorded in T_6 (100% RDN through urea 50% in each irrigation).

4.3.1.4.5 Available Phosphorus

The data on available P content of soil showed significant difference after harvest of crop (Table 4. 19). The available P content of soil ranged from 19.7 to 21.7 kg ha^{-1}. Highest available P was recorded in T_{14} which received 150%RDN through DSW (33.3% in each irrigation) (21.7 kg ha^{-1}), while lowest (19.7 kg ha^{-1}) was with T_{11} which received 100%RDN through DSW (33.3% in each irrigation).

4.3.1.4.5 Available Potassium

The data pertaining to available K content of soil influenced by ferti-irrigation of distillery spentwash is presented in Table 4. 19. Significantly highest available K content of soil was recorded in treatment T_3 (398.7 kg ha^{-1}) which received 150% RDN through distillery spentwash (in 6 irrigations) and was on par with T_2 (100% RDN through distillery spentwash (in 6 irrigations) (368.7 kg ha^{-1}), T_{15} (150 per cent RDN through distillery spentwash (50% in each irrigation) (366.8 kg ha^{-1}) and T_{14} (150% RDN through distillery spentwash (33.3% in each irrigation) (357.5 kg ha^{-1}). Significantly lowest

Table 4.19 : Effect of ferti-irrigation of primary spentwash on available nitrogen, phosphorus, potassium and sulphur content of soil after harvest of paddy

Parameters	Avail. N kg ha^{-1}	Avail.P_2O_5 kg ha^{-1}	Avail.K_2O kg ha^{-1}	Avail. S mg kg^{-1}
T_1: RDF (NPK) +FYM	311.9	20.8	287.1	14.8
T_2: 100% RDN through DSW (in 6 irrigations) +balance of P	306.1	21.4	368.7	12.6
T_3: 150% RDN through DSW (in 6 irrigations) +balance of P	312.9	21.4	398.7	13.1
T_4: 100%RDN through urea (20% in each irrigation) + RDP &RDK	301.7	19.8	281.5	12.3
T_5: 100%RDN through urea (33.3% in each irrigation)+ RDP &RDK	312.1	20.1	255.5	12.7
T_6: 100%RDN through urea (50% in each irrigation)+ RDP&RDK	299.3	20.2	267.4	12.9
T_7: 150%RDN through urea (20% in each irrigation)+ RDP &RDK	326.8	20.3	308.4	13.3
T_8: 150%RDN through urea (33.3% in each irrigation)+ RDP &RDK	321.2	20.4	291.3	13.7
T_9: 150%RDN through urea (50% in each irrigation)+ RDP&RDK	325.6	19.9	312.3	13.4
T_{10}: 100%RDN through DSW (20% in each irrigation)+ balance of P	317.3	20.0	328.7	13.7
T_{11}: 100%RDN through DSW (33.3% in each irrigation)+ balance of P	314.1	19.7	335.1	13.6
T_{12}: 100%RDN through DSW (50% in each irrigation) + balance of P	313.7	20.0	331.6	13.8
T_{13}: 150%RDN through DSW (20% in each irrigation)+ balance of P	319.5	21.3	341.1	14.0
T_{14}: 150%RDN through DSW (33.3% in each irrigation)+ balance of P	324.8	21.7	357.5	14.7
T_{15}: 150%RDN through DSW (50% in each irrigation)+ balance of P	321.4	20.2	366.8	13.4
SEm±	5.65	0.38	11.69	0.70
CD (5%)	16.38	1.10	33.87	NS

available K was observed with T_5 (255.5 kg ha^{-1}) but was on par with T_6 and T_4 treatments which recorded 267.4 and 281.5 kg ha^{-1} respectively.

4.3.1.4.6 Available Sulphur

The data on available S content of soil was not influenced by ferti-irrigation of distillery spentwash (Table 4.19). However, relatively highest value was recorded in treatment receiving 150% RDN through distillery spentwash 3splits followed by T_1 (14.7 & 14.8 mg kg^{-1})

4.3.1.4.7 Exchangeable Calcium

The data on exchangeable calcium (Ca) content of soil as influenced by ferti-irrigation of distillery spentwash is presented in Table 4.20. Significantly highest Ca (4.39 cmol (p^+) kg^{-1}) was recorded in treatment T_{15} which received 150% RDN through urea (50% in each irrigation) followed by T_{14} (ferti-irrigation at 150 per cent RDN through distillery spentwash (33% in each irrigation) (4.34 cmol (p^+) kg^{-1}) and 4.26 c mol (p^+) kg^{-1} in T_{13} .Whereas in chemical fertilizers applied treatments recorded significantly lower values compared to distillery spentwash applied treatments. However, highest (3.52 c mol (p^+) kg^{-1}) Ca content was recorded in 100% RDN through urea (50% in each irrigation).

4.3.1.4.8 Exchangeable Magnesium

Exchangeable magnesium content of soil as influenced by ferti-irrigation with distillery spentwash after harvest of paddy is presented in Table 4.20. Exchangeable Mg at harvest did not show significant difference. Relatively higher exchangeable Mg was found in T_{15} which received 150%RDN through DSW (50.0% in each irrigation) (2.25 c mol (p^+) kg^{-1}) and lowest (1.58 c mol (p^+) kg^{-1}) was recorded with T_1 receiving RDF+FYM.

4.3.1.4.9 Exchangeable Sodium

Ferti-irrigation with distillery spentwash significantly influenced the exchangeable sodium content of soil (Table 4.20). The highest exchangeable sodium

Table 4.20 : Effect of ferti-irrigation of primary spentwash on Exchangeable Ca, Mg and Na content of soil after harvest of Paddy

Parameters	Exch Ca c mol (p^+) kg^{-1}	Exch Mg c mol (p^+) kg^{-1}	Exch Na c mol (p^+) kg^{-1}
T_1: RDF (NPK) +FYM	3.61	1.58	0.202
T_2: 100% RDN through DSW (in 6 irrigations) +balance of P	4.03	1.92	0.360
T_3: 150% RDN through DSW (in 6 irrigations) +balance of P	4.13	2.04	0.445
T_4: 100%RDN through urea (20% in each irrigation) + RDP &RDK	3.35	1.87	0.176
T_5: 100%RDN through urea (33.3% in each irrigation)+ RDP &RDK	3.41	1.85	0.183
T_6: 100%RDN through urea (50% in each irrigation)+ RDP&RDK	3.52	1.86	0.179
T_7: 150%RDN through urea (20% in each irrigation)+ RDP &RDK	3.41	1.87	0.185
T_8: 150%RDN through urea (33.3% in each irrigation)+ RDP &RDK	3.42	1.88	0.187
T_9: 150%RDN through urea (50% in each irrigation)+ RDP&RDK	3.45	1.87	0.191
T_{10}: 100%RDN through DSW (20% in each irrigation)+ balance of P	4.08	1.93	0.207
T_{11}: 100%RDN through DSW (33.3% in each irrigation)+ balance of P	4.11	1.92	0.237
T_{12}: 100%RDN through DSW (50% in each irrigation) + balance of P	4.15	1.93	0.241
T_{13}: 150%RDN through DSW (20% in each irrigation)+ balance of P	4.26	2.02	0.300
T_{14}: 150%RDN through DSW (33.3% in each irrigation)+ balance of P	4.34	2.12	0.326
T_{15}: 150%RDN through DSW (50.0% in each irrigation)+ balance of P	4.39	2.25	0.445
SEm ±	0.02	0.14	0.06
CD (5%)	0.05	NS	0.19

content was recorded in distillery spentwash irrigated plots compared to ferti-irrigation with urea.

Significantly highest exchangeable sodium content was recorded in T_{14} (0.445 c mol (p^+) kg^{-1}) which received 150% RDN through distillery spentwash (in 6 irrigations) but was on par with T_{15} (0.445 c mol (p^+) kg^{-1}), T_2 (0.360 c mol (p^+) kg^{-1}), T_{14} (0.326 c mol (p^+) kg^{-1}) and T_{13}(0.300 c mol (p^+) kg^{-1}). Significantly lowest (0.176 c mol (p^+) kg^{-1}) exchangeable sodium content was recorded in T_4 (100% RDN through Urea (20% in each irrigation).

4.3.2 Field Experiment II- Effect of ferti-irrigation of spentwash on growth and yield of paddy in sodic soil.

4.3.2.1 Growth parameters

4.3.2.1.1 Plant height

The data pertaining to effect of ferti-irrigation of spentwash on plant height of paddy after reclamation of sodic soil are presented in Table.4.21. There was significant increase in plant height with the ferti-irrigation of spentwash compared to gypsum application. Highest plant height of 65.01cm was recorded with T_{10} treatment receiving RSW @ 100% GR+100% RDN through SW (4splits) followed by T_9 (RSW @ 100% GR+100% RDN through SW (3splits), T_8 (RSW @ 100% GR+50% RDN through SW (4splits) and T_7 (RSW @ 100% GR+50% RDN through SW (3splits)recorded 64.61cm, 63.11cm, 62.03 cm respectively and their effect was on par with each other. Lowest plant height (33.34cm) was recorded in T_1 (Gypsum @50% GR + Recommended NPK).

4.3.2.1.2 Number of productive tillers

The results pertaining to the ferti-irrigation of spentwash on number of productive tillers in paddy are presented in Table.4.21. No significant difference was noticed in number of productive tillers except gypsum applied plots. Highest (14.5) number of productive tillers was recorded in T_{10} RSW @ 100% GR+100% RDN through SW (4splits) followed by $T_{9.}$ $T_{8.}$ $T_{7,}$ T_6 compared to T_1 (Gypsum @50% GR + Recommended

Table 4.21 : Effect of ferti-irrigation of spentwash on growth & yield (q ha^{-1}) of paddy at VC farm, Mandya (Field experiment II)

Parameters	Plant height cm	No.of tillers	No.of seeds / panicle	Thousand grain weight (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1: Gypsum @50% GR + Recommended NPK	33.34	10.5	115	22.64	25.62	31.25
T_2: Gypsum @100% GR + Recommended NPK	35.29	11.2	120	24.72	33.02	38.21
T_3: RSW @ 50% GR +50% N through SW (3splits)	54.25	12.5	123	25.61	32.0	47.42
T_4: RSW @ 50% GR +50% N through SW (4 splits)	53.25	12.0	126	27.82	34.0	48.29
T_5: RSW @ 50% GR +100% N through SW (3splits)	56.33	12.5	130	27.71	35.75	49.40
T_6: RSW @ 50% GR +100% N through SW (4 splits)	56.03	13.5	129	28.12	35.0	48.54
T_7: RSW @ 100% GR+50% N through SW (3 splits)	62.03	13.5	136	30.40	36.0	51.50
T_8: RSW @ 100% GR+50% N through SW (4 splits)	63.11	14.0	134	32.67	37.25	50.86
T_9: RSW @ 100% GR+100% N through SW 3splits)	64.61	14.0	137	34.38	37.75	53.45
T_{10}: RSW @ 100% GR+100% N through SW (4splits)	65.01	14.5	135	32.32	36.75	54.50
T_{11}: 100% N (50 % N through RSW +50% N through SW in 3 splits)	48.37	11.5	120	25.69	32.98	44.97
T_{12}: 100% N (50 % N through RSW +50% N through SW in 4splits)	47.49	12.0	122	26.12	32.65	45.25
T_{13}: 150% N (50 % N through RSW +50% N through SW in 3 splits)	51.33	12.5	123	26.88	33.14	45.65
T_{14}: 150% N(50% N through RSW +50% N through SW in 4splits)	52.01	12.0	122	27.01	33.52	45.15
SEm±	0.71	0.43	4.68	0.89	0.36	0.37
CD(5%)	2.06	NS	13.62	2.59	1.06	1.09

NPK) and T_2 (Gypsum @100% GR + Recommended NPK) which recorded 10.5 and 11.2 number of tillers.

4.3.2.1.3 Number of seeds per panicle

Ferti-irrigation of spentwash did not influence the number of seeds per panicle (Table 4.21). Highest (137) number of seeds per panicle was recorded with application RSW @ 100% GR+100% RDN through SW 3splits) followed by T_7, T_{10}, T_8, T_5 which recorded 136, 135, 134 and 130 number of seeds per panicle. Significantly lowest (115) number of seeds per panicle was recorded in T_1 (gypsum @50% GR+ Rec NPK).

4.3.2.1.4 Thousand grain weight

The data pertaining to ferti-irrigation of spentwash on thousand grain weight of paddy after reclamation of sodic soil are presented in Table.4.21. There was significant increase in thousand grain weight with the application raw spentwash than gypsum application

Highest thousand grain weight of 34.38g was recorded with T_9 (RSW @ 100% GR+100% RDN through SW (3splits), followed by T_8 (32.67g), T_{10} (32.32g) which were on par with each other. Application of gypsum @100% GR + Recommended NPK recorded 24.72 g which was on par in T_3 (RSW @ 50% GR +50% RDN through SW (3splits) with, T_{11} (25.69 g), T_{12} (26.12 g) and T_{13} (26.88g) respectively. Lowest thousand grain weight (22.64 g) was recorded in (Gypsum @50% GR + Recommended NPK).

4.3.2.2 Yield

4.3.2.2.1 Grain yield

The data on the grain yield of paddy as influenced by ferti-irrigation of spentwash after reclamation of sodic soil is presented in Table.4.21. Significantly highest grain yield of 37.75 q ha^{-1} was recorded in T_9 (RSW @ 100% GR+100% RDN through SW (3splits), T_8 (37.25 q ha^{-1}) and T_{10} (36.75 q ha^{-1}). RSW @ 50% GR +100% RDN through SW (3splits) recorded 35.75 q ha^{-1} followed by T_5 (35.0 q ha^{-1}) but was significantly superior over T_4 (34.0 q ha^{-1}),T_{13} (33.14 q ha^{-1}),T_{14}(33.52 q ha^{-1}),T_2 (33.02 q ha^{-1}),T_3 (32.0 q ha^{-1}).

Lowest grain yield was recorded in T_1 (25.62 q ha^{-1}) which received gypsum @ 50% GR + recommended NPK.

4.3.2.2.2 Straw yield

Relevant data pertaining to straw yield of paddy as influenced by ferti-irrigation of spentwash after reclamation of sodic soil is presented in Table.4.21.

Significantly highest straw yield of 54.50 q ha^{-1} was recorded in T_{10} (RSW @ 100% GR+100% RDN through SW (4splits) followed by T_9 (53.45 q ha^{-1}). RSW @ 50% GR +100% RDN through SW (3splits) (T_5) recorded 49.40 q ha^{-1} followed by T_6 (48.54 q ha^{-1}), T_4 (48.24 q ha^{-1}) and was found significantly superior over T_2 (38.21 q ha^{-1}) and T_{11} (44.97 q ha^{-1}). Lowest straw yield (31.25 q ha^{-1}) was recorded in T_1 which received gypsum @ 50% GR + recommended NPK.

4.3.2.3 Nutrient composition of paddy

4.3.2.3.1 Nitrogen

The data pertaining to nitrogen (N) uptake by paddy at harvest is presented in Table 4.22. N uptake was significantly highest (119.7 kg ha^{-1}) with T_9 receiving (RSW @ 100% GR+100% RDN through SW (3splits) followed by T_{10} (117.6 kg ha^{-1}) and T_7 (115.9 kg ha^{-1}). RSW @ 50% GR +50% RDN through SW (3splits) recorded (108.9 kg ha^{-1}) followed by T_{14} (106.3 kg ha^{-1}) and T_4 (104.6 kg ha^{-1}) which was significantly superior over T_{13} (103.8 kg ha^{-1}), T_{12} (101.7 kg ha^{-1}). The treatment T_{11} (100% RDN (50 % RDN through RSW +50% RDN through SW in 4 splits) recorded 98.4 kg ha^{-1} which was significantly superior over T_2 receiving gypsum @100%GR+Rec.NPK (81.4 kg ha^{-1}). N uptake in (T_1) was significantly lowest (78.6 kg ha^{-1}) than other treatments.

4.3.2.3.2 Phosphorus

The result on phosphorus (P) uptake by paddy is presented in Table 4.22**.** Non-significant difference in P uptake by paddy crop at harvest was observed except in gypsum applied plots. P uptake was highest (18.1kg ha^{-1}) in T_{10} receiving RSW @ 100% GR+100% RDN through SW (4splits) followed by T_9 (17.2 kg ha^{-1}) and T_8 (16.9 kg ha^{-1}).

Table 4.22 : Effect of ferti-irrigation of primary spentwash on N, P, K, Ca, Mg and S uptake (kg ha^{-1}) by paddy at harvest (VC farm, Mandya- Field experiment II)

Parameters	N	P	K	Ca	Mg	S
T_1: Gypsum @50% GR + Recommended NPK	78.6	10.4	85.90	20.30	5.80	10.60
T_2: Gypsum @100% GR + Recommended NPK	81.4	11.6	90.40	27.70	6.60	12.50
T_3: RSW @ 50% GR +50% N through SW (3splits)	108.9	12.3	105.60	28.20	8.80	15.80
T_4: RSW @ 50% GR +50% N through SW (4 splits)	104.6	12.7	107.30	29.50	9.30	16.20
T_5: RSW @ 50% GR +100% N through SW (3splits)	112.1	13.0	109.80	30.20	9.90	16.70
T_6: RSW @ 50% GR +100% N through SW (4 splits)	110.2	13.3	113.50	30.90	10.20	16.90
T_7: RSW @ 100% GR+50% N through SW (3 splits)	115.9	16.2	119.40	30.50	11.40	17.10
T_8: RSW @ 100% GR+50% N through SW (4 splits)	114.2	16.9	121.10	31.20	11.90	17.50
T_9: RSW @ 100% GR+100% N through SW 3splits)	119.7	17.2	123.70	32.40	12.20	17.60
T_{10}: RSW @ 100% GR+100% N through SW (4splits)	117.6	18.1	124.80	33.80	12.80	17.70
T_{11}: 100% N (50 % N through RSW +50% N through SW in 3 splits)	98.4	11.8	97.30	25.90	8.00	13.60
T_{12}: 100% N (50 % N through RSW +50% N through SW in 4splits)	101.7	12.0	98.60	26.50	8.20	13.90
T_{13}: 150% N (50 % N through RSW +50% N through SW in 3 splits)	103.8	12.2	101.50	27.10	8.70	14.50
T_{14}: 150% N(50% N through RSW +50% N through SW in 4splits)	106.3	12.4	104.70	28.60	9.10	15.00
SEm±	1.54	1.42	3.09	0.46	0.31	0.44
CD (5%)	4.49	NS	8.97	1.35	0.90	1.28

RSW @ 50% GR +100% RDN through SW (4splits) recorded (13.3 kg ha^{-1}) and was found on par with T_5 (13.0 kg ha^{-1}), T_4 (12.7 kg ha^{-1}), T_{14} (12.4 kg ha^{-1}). Significantly lowest P uptake was recorded in T_1 (10.4 kg ha^{-1}) and was on par with T_2 (11.6 kg ha^{-1}).

4.3.2.3.3 Potassium

A significant difference in the potassium (K) uptake was found due to ferti-irrigation of spentwash to paddy crop (Table 4.22). Significant difference in K uptake was observed among the treatments. K uptake was significantly highest (124.8 kg ha^{-1}) in T_{10} (RSW @ 100% GR+100% RDN through SW (4splits) which was significantly superior over T_5 (109.8 kg ha^{-1}), T_4 (107.3 kg ha^{-1}), T_3 (105.6 kg ha^{-1}) and T_{14} (104.7 kg ha^{-1}) and was on par with T_9, T_8 and T_7. Significantly lowest K uptake was recorded in T_1 (85.9 kg ha^{-1}) which received gypsum @50% GR + Recommended NPK and was on par with T_2 (90.04 kg ha^{-1}) which received 100% GR

4.3.2.3.4 Calcium

The data pertaining to calcium (Ca) uptake by paddy at harvest is presented in Table 4.22. Application of spentwash significantly influenced the Ca uptake by paddy, recording highest value (33.80 kg ha^{-1}) in T_{10} (RSW @ 100% GR+100% RDN through SW (4 splits) and T_9 (32.40 kg ha^{-1}) which received RSW @ 100% GR+100% RDN through TSW (3splits). Significantly lowest Ca uptake was recorded in T_1 (20.3 kg ha^{-1}) which received gypsum @ 50% GR+rec.NPK.

4.3.2.3.5 Magnesium

The data on magnesium (Mg) uptake by paddy as influenced by raw spentwash application is presented in Table 4.22. Highest Mg uptake (12.80 kg ha^{-1}) was found in T_{10} (RSW @ 100% GR+100% RDN through SW (3splits) followed by T_9 (12.20 kg ha^{-1}) and T_8 (11.90 kg ha^{-1}). Significantly lowest uptake (5.80 kg ha^{-1}) was recorded in T_1 and was on par with T_2 (6.60 kg ha^{-1}) which received gypsum @50% GR and 100% GR respectively.

4.3.2.3.6 Sulphur

The results on Sulphur (S) uptake by paddy as affected by ferti-irrigation of spent wash is presented in Table 4.22. Uptake of sulphur was significantly highest (17.70 kg ha^{-1}) with T_{10} receiving (RSW @ 100% GR+100% RDN through SW (3splits) followed by T_9 (17.60 kg ha^{-1}) and T_8 (17.50 kg ha^{-1}) and was found on par with T_6 (16.90 kg ha^{-1}), T_5 (16.70 kg ha^{-1}), T_4 (16.20 kg ha^{-1}). Significantly lowest S uptake was recorded in T_1 (10.6 kg ha^{-1}).

4.3.2.4 Chemical properties of soil

4.3.2.4.1 Soil pH

Soil pH differed significantly due to ferti-irrigation of spentwash. (Table 4.23). The reduction in soil pH was highest (8.11) in T_9 (RSW @ 100% GR+100% RDN through SW (3splits) and lowest (8.79) was in T_1 (Gypsum @ 50% GR+ Rec.NPK).

4.3.2.4.2 Electrical conductivity

The effect of ferti-irrigation of spentwash on electrical conductivity (EC) of soil is presented in Table 4.23. In general, there was significant increase in soil EC in plots receiving spentwash compared to gypsum applied plots. Significantly highest EC (1.40 dS m^{-1}) value was recorded in T_{10} which received RSW @ 100% GR+100% RDN through TSW (4splits) followed by T_9 (RSW @ 100% GR+100% RDN through TSW (3splits)), T_8 (RSW @ 100% GR+50% RDN through TSW (4 splits)) which recorded values 1.14 dS $m^{-1}$and 1.09 dS m^{-1} compared to values 0.69 dS m^{-1} and 0.75 dS m^{-1} recorded by T_1 gypsum @ 50% GR+rec.NPK & T_2 (gypsum @ 100% GR) respectively.

4.3.2.4.3 Organic carbon

The organic carbon (OC) content of soil as influenced by ferti-irrigation of spentwash is given in Table 4.23. Increased application of raw spentwash progressively increased the organic carbon content of soil compared to gypsum plots.

Table 4.23 : Effect of ferti-irrigation of primary spentwash on pH, EC and OC content of soil after harvest of paddy at VC farm, Mandya (Field experiment II)

Parameters	pH (1:2)	EC (dS m^{-1})	OC (per cent)
T_1: Gypsum @50% GR + Recommended NPK	8.79	0.69	0.48
T_2: Gypsum @100% GR + Recommended NPK	8.60	0.75	0.50
T_3: RSW @ 50% GR +50% N through SW (3splits)	8.39	0.82	0.68
T_4: RSW @ 50% GR +50% N through SW (4 splits)	8.32	0.87	0.69
T_5: RSW @ 50% GR +100% N through SW (3splits)	8.34	0.97	0.70
T_6: RSW @ 50% GR +100% N through SW (4 splits)	8.31	1.02	0.72
T_7: RSW @ 100% GR+50% N through SW (3 splits)	8.29	0.98	0.75
T_8: RSW @ 100% GR+50% N through SW (4 splits)	8.25	1.09	0.77
T_9: RSW @ 100% GR+100% N through SW 3splits)s	8.19	1.14	0.78
T_{10}: RSW @ 100% GR+100% N through SW (4splits)	8.11	1.40	0.81
T_{11}: 100% N (50 % N through RSW +50% N through SW in 3 splits)	8.56	0.78	0.58
T_{12}: 100% N (50 % N through RSW +50% N through SW in 4splits)	8.53	0.82	0.60
T_{13}: 150% N (50 % N through RSW +50% N through SW in 3 splits)	8.50	0.93	0.65
T_{14}: 150% N(50% N through RSW +50% N through SW in 4splits)	8.51	0.95	0.67
SEm±	0.22	0.02	0.01
CD(5%)	0.68	0.06	0.03

Significant accumulation of OC (0.81percent) in soil was noticed in T_{10} (RSW @ 100% GR+100% RDN through SW (4splits) followed by T_9 RSW @ 100% GR+100% RDN through TSW (3splits) (0.78 percent), T_8 RSW @ 100% GR+50% RDN through TSW (4 splits) (0.77 percent), T_7 RSW @ 100% GR+50% RDN through TSW (3 splits) (0.75 per cent) and T_6 RSW @ 50% GR +100% RDN through TSW (4 splits) (0.72 percent) which was significantly superior over T_1 (Gypsum @50% GR + Recommended NPK) and T_2 (Gypsum @100% GR + Recommended NPK) recorded 0.48 per cent and 0.50 per cent respectively.

4.3.2.4.4 Available Nitrogen

The data pertaining to available N content of soil at different crop growth stages of paddy as influenced by ferti-irrigation of spentwash is presented in Table 4.24.

At tillering stage, ferti-irrigation of spentwash significantly influenced the available nitrogen content of soil. Significantly highest available N content was recorded in T_9 RSW @ 100% GR+100% RDN through TSW (3 splits) (439.9 kg ha^{-1}) followed by T_3 (438.3 kg ha^{-1}) and T_8 (436.5 kg ha^{-1}) which received RSW @ 100% GR+50% RDN through TSW (4splits).

Significantly lowest available nitrogen content was recorded in T_1 Gypsum @50% GR + Recommended NPK (226.4 kg ha^{-1}) which was on par with T_2 Gypsum @100% GR + Recommended NPK (232.5 kg ha^{-1}) which received gypsum @ 50% GR and 100% GR.

At flowering and harvest stages, available nitrogen content of soil followed the similar trend as that at tillering stage. RSW @100% GR recorded highest available nitrogen content (378.8 kg ha^{-1}) followed by RSW @ 50% GR, 150% and 100% RDN through spentwash and were significantly superior over gypsum @ 50 and 100% GR (186.9 and 182.4 kg ha^{-1}) respectively.

Table 4.24 : Effect of ferti-irrigation of primary spentwash on available NPK (kg ha^{-1}) content of soil at different growth stages of paddy at VC farm, Mandya(Field experiment II)

Parameters	Maximum tillering Stage			Flowering stage			After harvest		
	N	P	K	N	P	K	N	P	K
T_1: Gypsum @50% GR + Recommended NPK	226.4	18.7	303.7	200.6	16.2	286.1	186.9	14.2	279.2
T_2: Gypsum @100% GR + Recommended NPK	232.5	19.4	313.4	198.4	17.4	292.4	182.4	14.6	286.8
T_3: RSW @ 50% GR +50% N through SW (3splits)	438.3	22.3	387.1	386.8	20.8	369.6	374.8	19.4	342.6
T_4: RSW @ 50% GR +50% N through SW (4 splits)	428.4	22.5	384.4	387.4	20.4	367.4	363.4	19.3	356.7
T_5: RSW @ 50% GR +100% N through SW (3splits)	432.7	23.2	388.5	399.2	21.6	352.8	378.8	20.8	340.5
T_6: RSW @ 50% GR +100% N through SW (4 splits)	424.6	23.5	386.2	392.1	21.9	359.6	368.3	20.6	342.3
T_7: RSW @ 100% GR+50% N through SW (3 splits)	426.3	26.4	403.6	397.2	23.3	375.3	363.2	23.0	350.8
T_8: RSW @ 100% GR+50% N through SW (4 splits)	436.5	27.0	413.3	391.4	22.8	382.3	378.6	21.6	345.7
T_9: RSW @ 100% GR+100% N through SW 3splits)	439.9	28.6	422.2	416.8	25.6	388.5	374.7	24.1	368.7
T_{10}: RSW @ 100% GR+100% N through SW (4splits)	433.4	28.7	426.1	384.3	26.2	394.6	371.8	24.6	371.1
T_{11}: 100% N (50 % N through RSW +50% N through SW in 3 splits)	306.8	19.8	363.2	282.6	17.8	332.4	272.1	16.4	312.6
T_{12}: 100% N (50 % N through RSW +50% N through SW in 4splits)	310.7	20.3	369.3	286.2	17.4	335.5	269.5	16.2	308.3
T_{13}: 150% N (50 % N through RSW +50% N through SW in 3 splits)	334.8	20.7	377.4	299.1	18.6	348.7	287.3	17.8	320.4
T_{14}: 150% N(50% N through RSW +50% N through SW in 4splits)	356.7	18.7	378.4	301.5	18.2	350.6	285.4	18.0	321.8
SEm±	3.09	0.87	2.20	5.76	0.02	2.35	8.62	2.37	7.77
CD(5%)	8.97	2.53	6.41	16.73	0.05	6.83	25.07	NS	22.58

4.3.2.4.5 Available Phosphorus

The data on available P content of soil as influenced by ferti-irrigation of spentwash is presented in (Table 4.24). At tillering stage, ferti-irrigation of spentwash significantly influenced the available phosphorus content of soil. Significantly highest available P content was recorded in T_{10} RSW @ 100% GR+100% RDN through TSW (4splits) (28.7 kg ha^{-1}) followed by T_9 RSW @ 100% GR+100% RDN through TSW (3splits) (28.6 kg ha^{-1}), T_8 RSW @ 100% GR+50% RDN through TSW (4 splits) (27.0 kg ha^{-1}) and was significantly superior over 100 and 150% RDN through spentwash, and gypsum @50% GR (18.7 kg ha^{-1}) and 100% GR (19.4 kg ha^{-1}).

At flowering stage, available phosphorus content of soil followed the similar trend as that at tillering stage. Highest available P content was recorded in T_{10} (26.2 kg ha^{-1}) followed by T_9 (25.6 kg ha^{-1}) and was significantly superior over 100 and 150% RDN through spentwash, gypsum @50% GR (16.2 kg ha^{-1}) and 100% GR (17.4 kg ha^{-1}).

At harvest, there was no significant change in available P content of soil. However, highest P content was recorded in T_{10} (24.6 kg ha^{-1}) and lowest (14.2 kg ha^{-1}) in T_1 (gypsum @50% GR+ rec.NPK).

4.3.2.4.6 Available Potassium

The data pertaining to available K content of soil at different growth stages as influenced by ferti-irrigation of spentwash is presented in Table 4.24.

At tillering stage, ferti-irrigation of spentwash significantly influenced the available pottasium content of soil. Significantly highest available K content was recorded in T_{10} (426.1 kg ha^{-1}) followed by T_9 (422.2 kg ha^{-1}), T_8 (413.3 kg ha^{-1}) and was significantly superior over RSW @ 50% GR and 100 and 150% RDN through spentwash. Significantly lowest available K content was recorded in T_1 (303.7 kg ha^{-1}) which was on par with T_2 (313.4 kg ha^{-1}) which received gypsum @50% GR and 100%GR.

At flowering and harvest stage, available K content of soil followed the similar trend as that at tillering stage. At harvest , RSW @100% GR recorded highest available potassium content (371.1kg ha^{-1}) followed by RSW @50% GR, 150% and 100% RDN through spentwash and was significantly superior over gypsum@50 and 100% GR which recorded 286.8 and 279.2 kg ha^{-1} respectively.

4.3.2.4.7 Exchangeable Calcium

Application of raw spentwash had significant influence on exchangeable Ca content of soil (Table 4.25). RSW @100% GR recorded highest exchangeable Ca content (8.80 c mol (p+) kg^{-1}) followed by RSW @50% GR(7.60 c mol (p+) kg^{-1}) but was significantly superior over T_{14} which received 150% RDN through spentwash (7.10 c mol (p+) kg^{-1}), 100% RDN through spentwash (6.70 c mol (p+) kg^{-1}). Significantly lowest exchangeable Ca content of 6.3 and 7.1 c mol (p+) kg^{-1} was recorded in gypsum@ 50 and 100% GR respectively.

4.3.2.4.8 Exchangeable Magnesium

Exchangeable magnesium content of soil was significantly influenced by ferti-irrigation of spentwash (Table 4.25). Relatively highest exchangeable Mg content was recorded in T_{10} (4.17 c mol (p+) kg^{-1}) and was significantly superior over gypsum @100% (2.80 c mol (p+) kg^{-1}) and 50% GR(2.50 c mol (p+) kg^{-1}) and was on par with 150% RDN through spentwash (3.60 c mol (p+) kg^{-1}) and raw spentwash @50% GR (3.60 c mol (p+) kg^{-1}) in 3 splits .

4.3.2.4.9 Exchangeable Sodium and Exchangeable Sodium Percentage

Exchangeable sodium content of soil was significantly influenced by ferti-irrigation of spentwash is presented in (Table 4.25).Significantly lowest exchangeable Na content was recorded with application of raw spentwash @ 100%GR (5.20 c mol (p+) kg^{-1}) and raw spentwash @ 50% GR(5.60 c mol (p+) kg^{-1}). Significantly highest value (6.80 c mol (p^{+}) kg^{-1}) was recorded in T_1 (gypsum 50% GR+Rec.NPK) followed by 100 % RDN through raw spentwash (6.60 c mol (p^{+}) kg^{-1}) and 150% RDN (6.20 c mol (p^{+}) kg^{-1}).

Table 4.25 : Effect of ferti-irrigation of primary spentwash on exchangeable Ca, Mg, Na content of soil after harvest of paddy at VC farm, Mandya (Field experiment II)

Parameters	Ca cmol (p+) kg^{-1}	Mg cmol (p+) kg^{-1}	Na cmol (p+) kg^{-1}	ESP (%)
T_1: Gypsum @50% GR + Recommended NPK	6.30	2.50	6.80	31.68
T_2: Gypsum @100% GR + Recommended NPK	7.10	2.80	5.90	29.43
T_3: RSW @ 50% GR +50% N through SW (3splits)	7.30	3.53	5.70	27.89
T_4: RSW @ 50% GR +50% N through SW (4 splits)	7.50	3.47	5.60	27.61
T_5: RSW @ 50% GR +100% N through SW (3splits)	7.60	3.60	5.80	28.52
T_6: RSW @ 50% GR +100% N through SW (4 splits)	7.57	3.60	5.70	29.01
T_7: RSW @ 100% GR+50% N through SW (3 splits)	8.30	3.80	5.40	25.46
T_8: RSW @ 100% GR+50% N through SW (4 splits)	8.40	3.90	5.30	24.67
T_9: RSW @ 100% GR+100% N through SW 3splits)	8.60	4.03	5.40	26.28
T_{10}: RSW @ 100% GR+100% N through SW (4splits)	8.80	4.17	5.20	26.12
T_{11}: 100% N (50 % N through RSW +50% N through SW in 3 splits)	6.50	3.20	6.60	31.81
T_{12}: 100% N (50 % N through RSW +50% N through SW in 4splits)	6.70	3.30	6.50	31.62
T_{13}: 150% N (50 % N through RSW +50% N through SW in 3 splits)	6.90	3.50	6.20	30.54
T_{14}: 150% N(50% N through RSW +50% N through SW in 4splits)	7.10	3.60	6.20	30.38
SEm±	0.45	0.25	0.03	1.2
CD(5%)	1.31	0.71	0.08	3.9

Exchangeable Sodium Percentage of soil was also significantly influenced by ferti-irrigation of spentwash is presented in (Table 4.25). Significantly lowest exchangeable sodium percentage was recorded with application of raw spentwash @ 100%GR (24.67 per cent) and raw spentwash @ 50% GR (27.61 per cent). Significantly highest value (31.68 per cent) was recorded in T_1 (gypsum 50% GR+ Rec.NPK) followed by 100 % RDN through raw spentwash (31.81 per cent) and 150% RDN (30.54 per cent).

4.4 Effect of spentwash application of different dilutions on growth and yield of paddy - Green house experiment III

4.4.1 Growth parameters

4.4.1.1 Plant height

The relevant data pertaining to plant height, number of productive tillers, number of panicles, grain yield and straw yield are presented in Table 4.26.

The plant height of paddy differed significantly due to application of distillery spentwash at different dilutions. Significantly highest plant height (78.30 cm) was observed in T_1 (1:1dilution of Spentwash) and was significantly superior over T_4 (1:20 dilution) and T_5 (1:40 dilution) which recorded 74.30 cm and 71.32 cm respectively but was on par with treatments T_2 and T_3 respectively.

4.4.1.2 Number of productive tillers

The data pertaining to number of productive tillers after the harvest of paddy crop is presented in Table 4.26. In general, with decreasing dilution of spentwash, number of tillers progressively decreased. Application of distillery spentwash at 1:40 dilution recorded significantly lower (14.92) number of tillers compared to 1:1(17.92) and 1:5(16.90) dilutions but was on par with T_3 and T_4 which received 1:10 and 1:20 dilutions respectively and these treatments recorded 16.14 and 15.42 number of productive tillers.

4.4.1.3 Number of panicles

The data on the number of panicles at harvest of crop as influenced by application of different dilutions of distillery spentwash (DSW) are presented in Table 4.26.

Table 4.26 : Effect of application of spentwash of different dilutions on growth and yield parameters, grain & straw yield of paddy

Treatments	Plant height (cm)	No. of productive tillers	No. of Panicles	No. of filled grains /panicle	Grain yield (g pot^{-1})	Straw yield (g pot^{-1})
T_1: 1:1 dilution	78.30	17.92	20.95	105.07	14.21	27.57
T_2: 1:5 dilution	76.80	16.90	21.45	108.10	16.49	30.76
T_3: 1:10 dilution	76.30	16.14	20.44	117.58	20.07	27.26
T_4: 1:20 dilution	74.30	15.42	17.96	122. 34	21.58	26.11
T_5: 1:40 dilution	71.32	14.92	18.45	140.50	26.80	25.58
SEm±	1.26	0.73	0.45	6.43	1.42	0.91
CD (5%)	3.80	2.21	1.36	19.38	4.29	2.76

Significantly higher (21.45) number of panicles were observed in T_2 treatment receiving 1:5 dilution compared to 1: 20 & 1:40 dilution which recorded 17.96 and 18.45 number of panicles respectively. Application of distillery spentwash in 1: 10 dilution (T_3) recorded 20.44 panicles and the effect was on par with T_1 receiving 1:1 dilution which recorded (20.95) number of panicles.

4.4.1.4 Number of filled grains per panicle

Application of different dilutions of distillery spentwash (DSW) significantly influenced the number of filled grains per panicle (Table 4.26). Number of filled grains per panicle was significantly higher (140.50) in T_5 treatment receiving 1:40 dilution compared to T_3 receiving 1:10 dilution (117.58) but was on par with T_4 receiving 1:20 dilution (122.34). Application of distillery spentwash at 1:1 dilution recorded significantly lower (105.07) number of filled grains per panicle but was on par with distillery spentwash at 1:5 (T_2) which recorded 108.10 number of filled grains per panicle.

4.4.2 Yield

4.4.2.1 Grain yield

The data on grain yield of paddy as influenced by different dilutions of distillery spentwash is presented in Table 4.26. Grain yield of paddy was significantly increased with increasing dilutions of spentwash. Application of distillery spentwash at 1:40 dilution recorded significantly higher yield (26.80 g pot^{-1}) followed by 1:20 dilution (T_4) 21.58 g pot^{-1}. Significantly lower grain yield was recorded with 1: 1dilution (14.21g pot^{-1}) but was on par with distillery spentwash at 1:5 recorded grain yield of 16.49 g pot^{-1}.

4.4.2.2 Straw yield

Application of different dilutions of distillery spentwash significantly influenced the straw yield of paddy (Table 4.26). With the application of spentwash of lower dilutions the straw yield was gradually increased. Significantly highest straw yield was recorded with 1:5 dilution (30.76 g pot^{-1}) and was on par with 1:1 and 1:10 dilution.

Lowest straw yield of 25.58 g $pot^{-1}$was recorded in T_5 (1:40 dilution) but was on par with 1:20 times (26.11 g pot^{-1}) diluted spentwash.

4.4.3 Nutrient composition of paddy

4.4.3.1 Nitrogen

The effect of application of distillery spentwash of different dilutions on nitrogen (N) concentration and uptake by grain and straw at two different crop growth stages is presented in Table 4.27.

In general, decreasing dilutions of spentwash progressively decreased the N concentration. At flowering stage, treatment receiving 1:1 diluted spentwash recorded relatively higher N concentration of (1.32 per cent) but was on par with 1:5 dilution (1.25 per cent) and was significantly superior over other lower dilutions of distillery spentwash. Significantly lowest nitrogen content was recorded in T_5 (0.99 per cent).

At harvest, highest N concentration in grain was observed with application of distillery spentwash in 1:1dilution (1.04 per cent) followed by and 1:5 (0.98 per cent) dilutions. Distillery spentwash diluted 40 times recorded significantly lower N concentration (0.61 per cent) but was on par with T_4 (1:20 dilution) (0.69 per cent).Similar trend was noticed with N concentration in straw. Significantly highest value was recorded in T_1 (0.284 per cent) and was lowest (0.120 per cent) was in T_5 (1:40 dilution).

Total N uptake by paddy crop differed significantly with different dilutions of spentwash. In general with decreasing dilutions, the N uptake by paddy crop increased significantly compared to lower dilutions. Significantly highest N uptake was recorded in T_5 (80.04 mg pot^{-1}) followed by T_4 (78.40 mg pot^{-1}) receiving 1:20 and 1:40 dilutions respectively. Treatment T_1 which received 1:1 dilution recorded lowest N uptake (70.04 mg pot^{-1}) and was on par with T_2 (72.75 mg pot^{-1}) and T_3(75.59 mg pot^{-1}) respectively.

Table 4.27 : Effect of application of spentwash of different dilutions on nutrient uptake by paddy

Treatments	Flowering stage (per cent) Nutrient concentration			Nutrient content at harvest (per cent) and their total uptake (mg pot^{-1})								
				N			P			K		
	N	P	K	Grain	Straw	Total uptake	Grain	Straw	Total uptake	Grain	Straw	Total uptake
T_1: 1:1 dilution	1.32	0.082	0.71	1.04	0.284	70.04	0.150	0.055	16.86	1.19	0.45	64.03
T_2: 1:5 dilution	1.25	0.067	0.63	0.98	0.235	72.75	0.140	0.057	16.92	1.13	0.29	65.90
T_3: 1:10 dilution	1.17	0.060	0.54	0.72	0.239	75.59	0.110	0.041	17.32	1.08	0.29	68.71
T_4: 1:20 dilution	1.04	0.055	0.50	0.69	0.175	78.40	0.120	0.033	18.24	0.98	0.28	74.54
T_5: 1:40 dilution	0.99	0.045	0.47	0.61	0.120	80.04	0.100	0.024	19.18	0.87	0.25	76.52
SEm±	0.025	0.006	0.03	0.028	0.019	2.25	0.004	0.002	0.36	0.029	0.012	1.51
CD (5%)	0.078	0.018	0.11	0.08	0.058	6.79	0.012	0.006	1.11	0.089	0.038	4.56

4.4.3.2 Phosphorus

The results on phosphorus (P) concentration in paddy as affected by application of spentwash as different dilutions at two different growth stages are presented in Table 4.27. Different dilutions of distillery spentwash significantly influenced the P concentration at two different growth stages of crop growth.

At flowering stage, significantly higher P concentration was observed in T_1 (0.082 per cent) and was on par with T_2 (1:5 dilution) (0.067 per cent). Lowest P concentration was observed with distillery spentwash at 1:40 dilution (0.045 per cent).

At harvest, relatively higher P concentration was noticed in T_1 (0.150 per cent), which received 1:1 dilution and in treatment T_2 which received 1: 5 dilution (0.140 per cent) treatments accumulated significantly higher P concentration in grain compared to all other treatments. Significantly lowest P concentration was recorded in T_5 (0.100) in 1:40 dilution. Similar trend was noticed with respect to P concentration in straw also. Significantly highest P concentration was recorded in T_2 (0.057 per cent) and lowest was with T_5 (0.024 per cent) which received 1:40 dilution.

Total P uptake by paddy crop was influenced significantly with application of spentwash of different dilutions. In general with decreasing dilutions, the P uptake by paddy crop increased significantly compared to lower dilutions. Significantly highest P uptake was recorded in T_5 (19.18 mg pot^{-1}) followed by T_4 (18.24 mg pot^{-1}) receiving 1:20 dilution. Application of distillery spentwash in 1:1 dilution recorded lowest P uptake (16.86 mg pot^{-1}) and was on par withT_2 (16.92 mg pot^{-1}) and T_3 (17.32 mg pot^{-1}) respectively.

4.4.3.3 Potassium

There were significant differences in the potassium (K) concentration of paddy crop at all growth stages due to application of different dilutions of distillery spentwash to paddy (Table 4.27). In general, increasing dilutions of spentwash progressively increased the K concentration.

At flowering stage, treatment receiving 1:1 diluted spentwash recorded relatively higher K concentration of (0.71 per cent) but was on par with 1:5 dilution (0.63 per cent) and was significantly superior over other lower dilutions of distillery spentwash. Significantly lowest potassium concentration (0.47 per cent) was recorded in T_5 which received 1:40 dilution.

At harvest, highest K concentration in grain was observed with application of 1:1dilution (1.19 per cent) and 1:5 dilution (1.13 per cent). Distillery spentwash diluted 40 times recorded significantly lower (0.87per cent) K concentration compared to T_4 (1:20times dilution) (0.98 per cent). Similar trend was noticed with K concentration in straw. Significantly highest K concentration in straw was recorded in T_1 (0.45 per cent) and lowest (0.25 per cent) was in T_5 which received 1:40 dilution.

Total K uptake in paddy crop differed significantly with different dilutions of spentwash. Significantly highest K uptake was recorded in T_5 (76.52 mg pot^{-1}) followed by T_4 (74.54 mg pot^{-1}) which received 1:40 dilution and 1:20dilution respectively. Treatment T_1 which received 1:1 dilution recorded lowest K uptake (64.03 mg pot^{-1}) and was on par with T_2 receiving 1:5 dilution (65.90 mg pot^{-1}) and T_3 receiving 1:10 dilution of spentwash (68.71 mg pot^{-1}) respectively.

4.4.3.4 Sulphur

Application of distillery spentwash of different dilutions significantly influenced the sulphur (S) concentration of paddy crop (Table 4.28). At harvest, different dilutions of distillery spentwash significantly influenced the S concentration highest value was recorded with 1:40 dilution of distillery spentwash (14.62 mg pot^{-1}) followed by 1:20 dilution of distillery spentwash (12.27 mg pot^{-1}) and were significantly superior over all other treatments.

4.4.3.5 Calcium

The data pertaining to calcium (Ca) uptake by paddy at harvest stage is presented in Table 4.28. At harvest, application of distillery spentwash in different dilutions significantly influenced the Ca uptake by paddy recording highest value with 1:40 times

Table 4.28 : Effect of application of spentwash of different dilutions on secondary and micro- nutrients uptake (mg pot^{-1}) at harvest of paddy

Treatments	Ca	Mg	S	Fe	Mn	Zn	Cu
T_1: 1:1 dilution	36.37	20.52	9.30	24.73	9.22	1.71	2.10
T_2: 1:5 dilution	36.23	21.80	10.11	26.81	10.14	1.80	2.51
T_3: 1:10 dilution	38.76	22.75	11.75	29.04	13.63	1.92	2.82
T_4: 1:20 dilution	42.22	23.67	12.27	32.18	15.52	2.07	3.14
T_5: 1:40 dilution	43.92	23.65	14.62	39.43	16.34	2.21	3.55
SEm±	0.64	0.58	0.98	1.51	0.63	0.09	0.22
CD (5%)	1.93	1.74	2.94	4.54	1.89	NS	NS

dilution of distillery spentwash (43.92 mg pot^{-1}) followed by 1:20 times diluted distillery spentwash (42.22 mg pot^{-1}). Treatment T_3 which received 1:10 times diluted effluent recorded Ca uptake 38.76 mg pot^{-1} which was significantly superior over treatments T_1 & T_2 receiving 1:1 and 1:5 dilutions recorded lowest uptake of 36.37 & 36.23 mg pot^{-1} respectively.

4.4.3.6 Magnesium

The data on magnesium (Mg) uptake by paddy at harvest as influenced by different dilutions of distillery spentwash is presented in Table 4.28. At harvest, highest (23.67 mg pot^{-1}) Mg uptake was found with distillery spentwash at 1:40 and was found on par with 1:20 times dilution of distillery spentwash followed by T_5 (1:40 times dilution) and T_3 (1:10times dilution). Significantly lowest uptake of Mg was recorded in T_1 (20.52 mg pot^{-1}) which received 1: 1 dilution.

4.4.3.7 Iron

The effect of different dilutions of distillery spentwash on iron (Fe) uptake by paddy is presented in Table 4.28. At harvest, application of distillery spentwash in different dilutions significantly influenced the Fe uptake by paddy crop. Highest value (39.43 mg pot^{-1}) was recorded with 1:40 times diluted distillery spentwash followed by 1:20 times diluted distillery spentwash (32.18 mg pot^{-1}). Treatment T_3 which received 1:10 times diluted effluent recorded 29.04 mg pot^{-1} which was significantly superior over T_1 receving 1:1 diluted spentwash (24.73 mg pot^{-1}) and was on par with T_2 (26.81 mg pot^{-1}) which received 1:5 times diluted spentwash.

4.4.3.8 Manganese

Application of spentwash of different dilutions significantly influenced the manganese (Mn) uptake by paddy at harvest (Table 4.28). Mn uptake was significantly highest (16.34 mg pot^{-1}) in treatment which received 1:40 times dilution of distillery spentwash followed by 1:20 times diluted distillery spentwash (15.52 mg pot^{-1}). Least Mn uptake (9.22 mg pot^{-1}) was recorded in T_1 (1: 1 dilution) and was on par with T_2 (1:5 dilution) recorded 10.14 mg pot^{-1} respectively.

4.4.3.9 Copper

The data on Copper (Cu) uptake by paddy as influenced by different dilutions of distillery spentwash is presented in Table 4.28. Application of spentwash of different dilutions had no significant effect on Copper (Cu) uptake by paddy at harvest. However, highest uptake was recorded in T_5 (3.55 mg pot^{-1}) which received 1:40 times dilution of distillery spentwash and least Cu uptake(2.10 mg pot^{-1}) was recorded in T_1 (1: 1 dilution).

4.4.3.10 Zinc

The data on zinc (Zn) uptake by paddy is presented in Table 4.28. Zinc (Zn) uptake by paddy was not significantly influenced by different dilutions of distillery spentwash However, highest uptake was recorded in T_5 (2.21 mg pot^{-1}) which received 1:40 times diluted distillery spentwash and least Zn uptake (1.71 mg pot^{-1}) was recorded in T_1 (1: 1 dilution).

4.4.4 Chemical properties of soil

4.4.4.1 Soil pH

The data pertaining to the effect of spentwash of different dilutions on soil pH after the harvest of paddy crop is given in Table**.**4.29**.** Soil pH differed significantly due to different dilutions of distillery spentwash. Significantly higher soil pH (6.81) was recorded in T_1 (1:1 dilution) compared to initial value (6.18). With increasing dilutions of distillery spentwash Soil pH decreased progressively. Significantly lowest pH value (6.11) was recorded in T_5 (1:40 times dilution) followed by T_4 (6.33) (1:20 times diluted). At lower dilutions, significantly highest pH value (6.81and 6.76) was recorded in treatments receiving 1:1 (T_1) and 1:5 (T_2) times diluted spentwash respectively.

4.4.4.2 Electrical conductivity

The data on electrical conductivity (EC) of soil as influenced by spentwash of different dilutions after the harvest of crop is presented in Table 4.29. Significantly highest EC (0.56 d S m^{-1}) was recorded in T_1 (1:1 dilution) compared to initial value

Table 4.29 : Effect of application of spentwash of different dilutions on nutrient status of soil after harvest of paddy

Treatments	pH 1:2.5	EC dS m^{-1}	OC per cent	Avail.N kg ha^{-1}	Avail.P kg ha^{-1}	Avail.K Kg ha^{-1}	Avail S mg kg^{-1}
T_1: 1:1 dilution	6.81	0.56	0.60	318.02	23.05	418.15	10.64
T_2: 1:5 dilution	6.76	0.50	0.56	307.08	22.85	404.61	9.91
T_3: 1:10 dilution	6.34	0.42	0.54	273.42	21.40	377.82	8.26
T_4: 1:20 dilution	6.33	0.38	0.51	259.02	20.63	371.55	7.07
T_5: 1:40 dilution	6.11	0.20	0.48	232.50	19.61	357.57	5.09
SEm±	0.06	0.038	0.018	7.62	1.26	8.01	0.50
CD (5%)	0.20	0.11	0.055	22.96	3.82	24.14	1.51

(0.15). Similar trend as that of pH was noticed. Electrical conductivity value of 0.50 d Sm^{-1} was recorded in T_2 and was on par with T_3 (1:5 dilution) (0.42 dS m^{-1}). The lowest EC value (0.20 dS m^{-1}) was recorded in T_5 (1:40 dilution).

4.4.4.3 Organic carbon

Application of distillery spentwash of different dilutions significantly influenced the organic carbon content of soil Table 4.29. The highest organic carbon content was recorded in treatment receiving spentwash of lower dilutions and decreased with higher dilutions. Significantly highest (0.60 per cent) organic carbon content was recorded in T_1 but was on par with 1: 5times diluted treatment. Treatment which received 1:10 times diluted distillery spentwash recorded OC value of 0.54 per cent and was on par with 1:20 times diluted spentwash (0.51 per cent). Lowest organic carbon content of 0.48 was recorded in T_5 (1:40 times dilution).

4.4.4.4 Available Nitrogen

Available nitrogen content of soil was significantly influenced by the application of diluted distillery spentwash Table 4.29. With increasing dilutions of spentwash, there was gradual decrease in available nitrogen content of soil after harvest of crop. The highest available nitrogen content of soil (318.02 kg ha^{-1}) was recorded in T_1 which received 1:1 dilution of spentwash, which was found on par with T_2 (307.08 kg ha^{-1}). Treatments receiving 1:10 dilution recorded significantly highest (273.42 kg ha^{-1}) available N content over T_5 (232.50 kg ha^{-1}) treatment receiving 1:40 times dilution of spentwash and was on par with T_4 (1:20 times dilution) which recorded 259.02 kg ha^{-1}.

4.4.4.5 Available Phosphorus

The data on available P content of soil showed significant difference due to application of diluted spentwash after harvest of crop (Table 4.29). The available P content of soil ranged from 19.61 to 23.05 kg ha^{-1}. Highest available P was recorded in T_1 receiving 1:1 diluted spentwash, while lowest was with T_5 receiving (1:40 time's dilution).

4.4.4.6 Available Potassium

The data pertaining to available K content of soil at different growth stages as influenced by distillery spentwash of different dilutions is presented in Table 4.29. Significantly highest available K in soil was recorded with T_1 receiving 1:1 diluted spentwash (418.15 kg ha^{-1}) over all other treatments and was on par with T_2 receiving 1:5 times diluted spentwash. (404.61 kg ha^{-1}). Significantly lowest available K was observed with T_5 receiving 1:40 times diluted spentwash (357.57 kg ha^{-1}) but was on par with T_3 (377.82 kg ha^{-1}) and T_4 (371.55 kg ha^{-1}) which received 1:10 and 1:20 times diluted spentwash respectively.

4.4.4.7 Available Sulphur

The data on available S content of soil as influenced by distillery spentwash of different dilutions of spentwash is given in Table 4.29. With the increasing dilutions of distillery spentwash the available S content of soil progressively decreased. Highest S content was observed in T_1 which received 1:1 dilution (10.64 mg kg^{-1}) and was on par with T_2 receiving 1:5 dilution (9.91 mg kg^{-1}). Significantly lower available S content was observed with T_5 receiving1:40 times diluted spentwash. (5.09 mg kg^{-1})

4.4.4.8 Exchangeable Calcium

Relevant data pertaining to effect of application of spentwash of different dilutions on exchangeable Ca content of soil is presented in Table 4.30. Highest exchangeable Ca was recorded with T_1(3.01 c mol (p^+) kg^{-1}), T_2 (2.93 c mol (p^+) kg^{-1}) and T_3 (2.80 c mol (p^+) kg^{-1}) which received application of distillery spentwash at 1:1, 1:5 and 1:10 were found significantly superior over other two treatments. Application of distillery spentwash 1:40 dilution recorded significantly lowest exchangeable Ca (2.58 c mol (p^+) kg^{-1}).

4.4.4.9 Exchangeable Magnesium

Exchangeable magnesium content of soil after harvest of paddy was significantly influenced by application of spentwash of different dilutions (Table 4.30). Exchangeable Mg content of soil did not show significant difference. Relatively higher exchangeable

Table 4.30 : Effect of application of spentwash of different dilutions on secondary and micro- nutrients status of soil after harvest of paddy

Treatments	Exch.Ca c mol (p+) kg^{-1}	Exch.Mg c mol (p+) kg^{-1}	Exch.Na c mol (p+) kg^{-1}	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Cu mg kg^{-1}
T_1: 1:1 dilution	3.01	1.86	0.403	26.31	5.49	1.56	2.55
T_2: 1:5 dilution	2.93	1.49	0.386	26.01	5.15	1.31	2.37
T_3: 1:10 dilution	2.80	1.37	0.315	25.90	5.00	1.28	2.05
T_4: 1:20 dilution	2.62	1.32	0.293	25.77	4.88	1.24	1.94
T_5: 1:40 dilution	2.58	1.18	0.187	24.66	4.20	1.22	1.86
SEm±	0.08	0.06	0.02	0.91	0.06	0.07	0.06
CD (5%)	0.24	0.19	0.06	NS	0.19	NS	0.19

Mg was found with distillery spentwash 1:1 dilution (1.86 c mol (p^+) kg^{-1}) and lowest was recorded with T_5 (1.18 c mol (p^+) kg^{-1}).

4.4.4.10 Exchangeable Sodium

Application of distillery spentwash of different dilutions significantly influenced the exchangeable sodium content of soil (Table 4.30). The highest exchangeable sodium content was recorded in treatments receiving spentwash of lower dilutions and the values decreased with higher dilutions.

Significantly highest exchangeable sodium content was recorded in T_1 (0.403 cmol (p^+) kg^{-1}) but was on par with 1: 5 times diluted treatment (0.386 c mol (p^+) kg^{-1}). 1:10 times diluted spentwash recorded exchangeable sodium value of 0.315 cmol (p^+) kg^{-1} and was on par with 1:20 times diluted spentwash (0.293 c mol (p^+) kg^{-1}). Lowest exchangeable sodium content of 0.187 c mol (p^+) $kg^{-1}$was recorded in T_5 (1:40 dilution).

4.4.4.11 DTPA-Fe

The data on DTPA-Fe content of soil as influenced by different dilutions of distillery spentwash is given in Table 4.30. There was no significant difference in DTPA extractable Fe content of soil. However, with the increasing dilutions of distillery spentwash the DTPA-Fe content of soil decreased progressively. Highest DTPA extractable Fe content was observed with T_1 receiving 1:1 dilution (26.31 mg kg^{-1}) and lower DTPA-Fe content was observed with T_5 receiving 1: 40 times diluted spentwash (24.66 mg kg^{-1})

4.4.4.12 DTPA-Mn

Application of different dilutions of distillery spentwash influenced the DTPA extractable Mn content of soil (Table 4.30). The highest DTPA-Mn content of soil (5.49 mg kg^{-1}) was recorded in T_1 which received 1:1 dilution of spentwash, which was superior to all other treatments. Significantly lowest DTPA extractable Mn was observed with T_5 which received1:40 times diluted spentwash (4.20 mg kg^{-1}).

4.4.4.13 DTPA-Zn

Application of spentwash of different dilutions of distillery spentwash did not influence DTPA extractable Zn content of soil (Table 4.30). The highest DTPA-Zn content of soil (1.56 mg kg^{-1}) was recorded in T_1 (1:1 dilution) which was significantly superior over all other treatments. Lowest DTPA extractable Zn was observed with T_5 which received 1:40 times dilution (1.22 mg kg^{-1}).

4.4.4.14 DTPA-Cu

Results on the effect of application of spentwash of different dilutions on DTPA extractable Cu content of soil is presented in Table 4.32. The highest DTPA-Cu content of soil (2.55 mg kg^{-1}) was recorded in T_1 receiving (1:1 dilution) which was on par with T_2 receiving1:5 times diluted spentwash (2.37 mg kg^{-1}) and were found significantly superior over all other treatments. Lowest DTPA extractable Cu was observed with T_5 which received 1: 40 times diluted spentwash (1.86 mg kg^{-1})

4.5 Cost economics

4.5.1 Cost economics of reclamation of sodic soil using raw spentwash and gypsum

The cost of cultivation of rice as influenced by raw spentwash application was worked out per hectare for one season. Application of raw spentwash @ 5.0 lakh liters ha^{-1} + balance of P through fertilizers (T_4) was economically beneficial than recommended NPK (without amendment) (T_1) and Gypsum @100% GR + Recommended NPK (T_2).

Economics of production of rice by raw spentwash application has been presented in Table 4.31. The lowest total cost of cultivation (13047 $Rs.ha^{-1}$) was recorded in raw spentwash @ 7.5 lakh liters ha^{-1} + balance of P (T_5) and highest (53981 $Rs.ha^{-1}$) was recorded with gypsum @100% GR + recommended NPK ($T_{2)}$.

Highest gross returns (39241$Rs.ha^{-1}$) was recorded in raw spentwash @ 5.0 lakh liters ha-^{1} + balance of P (T_4) followed (38485$Rs.ha^{-1}$) by raw spentwash @ 7.5 lakh

Table 4.31 : Effect of raw spentwash application on gross returns, net returns and B:C ratio of paddy at VC farm Mandya (Field experiment I)

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B :C ratio
T_1: Recommended NPK (without amendment)	17.48	18.30	14981	15082	101	1.01
T_2: Gypsum @100% GR + Recommended NPK	36.32	37.07	53981	31280	-22701	0.58
T_3: Raw Spentwash @ 2.5 lakh liters ha^{-1}	39.69	42.65	13394	34311	20917	2.56
T_4: Raw Spentwash @ 5.0 lakh liters ha^{-1}	45.18	51.62	13220	39241	26021	2.97
T_5: Raw Spentwash @ 7.5 lakh liters ha^{-1}	44.75	54.86	13047	38485	25438	2.95

Note: Urea @ Rs. 4.80/ kg, SSP@ Rs. 3.705/ kg, MOP @ Rs. 4.50/ kg, Gypsum@ Rs.3/kg ,Paddy -@ Rs.800/q, Paddy straw-@ Rs.60/q, liters ha-^{1} + balance of P through fertilizers (T_5) and least gross return (15082 Rs. ha^{-1}) was recorded with recommended NPK (without amendment) (T_1).

The highest benefit cost ratio (2.97) was recorded with raw Spentwash @ 5.0 lakh liters ha^{-1} + balance of P through fertilizers (T_4) followed (2.95) by raw Spentwash @ 7.5 lakh liters ha^{-1} + balance of P through fertilizers (T_5) and least (0.58) was with gypsum @100% GR + recommended NPK (T_2).

4.5.2 Cost economics of ferti- irrigation of primary spentwash

The cost of cultivation of rice as influenced by raw spentwash irrigation and ferti-irrigation with primary spentwash was worked out per hectare for one season. Application of raw spentwash @ 100% GR + 100% RDN through SW 3splits) (T_9) was economically beneficial than gypsum @100% GR + recommended NPK (T_2) and gypsum @50% GR + recommended NPK (T_1).

Economics of production of rice by raw spentwash ferti-irrigation has been presented in Table 4.32. The lowest total cost of cultivation (12410 Rs.ha^{-1}) was recorded in raw spentwash @ 100% GR+100% RDN through SW 3splits) (T_9) and highest (53981 Rs.ha^{-1}) was recorded with gypsum @100% GR + recommended NPK (T_2).

Highest gross return (33407 Rs.ha^{-1}) was recorded in raw spentwash @ 100% GR+100% RDN through SW 3splits) (T_9) followed (32852 Rs.ha^{-1}) by raw spentwash @ 100% GR+50% RDN through SW (4 splits) (T_8) and least gross return (22371 Rs. ha^{-1}) was recorded with gypsum @50% GR + recommended NPK (T_1).

The highest benefit cost ratio (2.69) was recorded with raw spentwash @ 100% GR+100% RDN through SW 3splits) (T_9) followed (2.65) by raw spentwash @ 100% GR+50% RDN through SW (4 splits) (T_8) and least (0.53) with gypsum @100% GR + recommended NPK (T_2).

Table. 4.32 : Effect of ferti- irrigation of spentwash on gross returns, net returns and B:C ratio of paddy at VC farm, Mandya (Field experiment II)

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B :C ratio
T_1: Gypsum @50% GR + Recommended NPK	33.34	10.5	34481	22371	-12110	0.65
T_2: Gypsum @100% GR + Recommended NPK	35.29	11.2	53981	28709	-25272	0.53
T_3: RSW @ 50% GR +50% RDN through SW (3splits)	54.25	12.5	12410	28445	16035	2.29
T_4: RSW @ 50% GR +50% RDN through SW (4 splits)	53.25	12.0	12410	30097	17687	2.43
T_5: RSW @ 50% GR +100% RDN through SW (3splits)	56.33	12.5	12410	31564	19154	2.54
T_6: RSW @ 50% GR +100% RDN through SW (4 splits)	56.03	13.5	12410	30912	18502	2.49
T_7: RSW @ 100% GR+50% RDN through SW (3 splits)	62.03	13.5	12410	31890	19480	2.57
T_8: RSW @ 100% GR+50% RDN through SW (4 splits)	63.11	14.0	12410	32852	20442	2.65
T_9: RSW @ 100% GR+100% RDN through SW 3splits)	64.61	14.0	12410	33407	20997	2.69
T_{10}: RSW @ 100% GR+100% RDN through SW (4splits)	65.01	14.5	12410	32670	20260	2.63
T_{11}: 100% RDN (50 % RDN through RSW +50% RDN through SW in 3 splits)	48.37	11.5	13498	29082	15584	2.15
T_{12}: 100% RDN (50 % RDN through RSW +50% RDN through SW in 4splits)	47.49	12.0	13498	28835	15337	2.14
T_{13}: 150% RDN (50 % RDN through RSW +50% RDN through SW in 3 splits)	51.33	12.5	13464	29251	15787	2.17
T_{14}: 150% RDN(50% RDN through RSW +50% RDN through SW in 4splits)	52.01	12.0	13464	29525	16061	2.19

Note: Urea @ Rs. 4.80/ kg, SSP@ Rs. 3.705/ kg, MOP @ Rs. 4.50/ kg, Gypsum@ Rs.3/kg ,Paddy -@ Rs.800/q, Paddy straw-@ Rs.60/q,

DISCUSSION

V. DISCUSSION

The escalating prices of fertilizers has resulted in application of less quantity of nutrients than the actual crop demand, thus leading to excessive mining of nutrients from soil and deterioration of soil health . In this context the high concentration of nutrients present in spentwash offers a very good opportunity to use it as a wholesome liquid fertilizer and as an ameliorant for reclamation of sodic soils as it is rich source of calcium.

The investigation on utilization of raw spentwash for reclamation of sodic soil and ferti-irrigation studies with distillery spentwash on paddy was designed to address the problem of reclamation of sodic soil. The experiments consisted of (a) green house experiment at GKVK and field experiment at VC, farm Mandya with paddy as test crop on reclamation of sodic soil using spentwash and gypsum (b) another green house experiment at GKVK and field experiment at VC, farm Mandya on ferti-irrigation of spentwash with paddy as a test crop. (c) Green house experiment to study the effect of spentwash of different dilutions on paddy crop. The results obtained in these experiments are discussed in this chapter.

5.1 Characterization of distillery spentwash

The chemical composition of raw and treated distillery spentwash presented in Table 4.1 revealed that raw spentwash samples collected from M/s Chamundeshwari Distilleries Private Limited, K.M. Doddi, Maddur Taluk, Mysore district, was highly acidic in nature (pH 4.11), high in salt content with an electrical conductivity of 17.70 dS m^{-1}. It also has appreciable quantities of total suspended solids (SS) (1.43 percent) and total dissolved solids content (5.20per cent). The pollution load in terms of biological oxygen demand (BOD) and chemical oxygen demand (COD) was quite high with BOD load of 35320 mg L^{-1} and COD load of 94650 mg L^{-1}. The high salt content of spentwash with high BOD and COD load threatens the disposal of distillery spentwash on land or on water bodies (Mohammed Haroon and Subash Chandra Bose, 2004) .The concentration of nitrogen, phosphorus and potassium were 0.19, 0.03, and 0.88 per cent respectively. It also has good amount of calcium, magnesium and sodium and the values were 2600, 1700, 300.80 mg L^{-1} respectively. The high concentration of Ca in spentwash imparts the potential in reclaiming sodic soils similar to that of gypsum effect (Santiago Mahimaraja and Nanthi Bolan, 2004). Thus it can be effectively used as a source of plant nutrients and as soil amendment. The concentration of iron, manganese, zinc and copper in raw spentwash was 18.0, 5.8, 0.83and 1.2 mg L^{-1} respectively. The high concentration of the nutrients present in spentwash is mainly due to their uptake by sugarcane crop and due to addition of some of the nutrients during distillation or during biomethanation.

On the other hand, the primary treated spentwash also called post methanated spentwash has neutral pH reaction (pH 7.22), with the electrical conductivity of 8.89 dS m^{-1}. Total suspended solids (SS) and total dissolved solids (TDS) content were 2.41 per cent and 1.24 per cent respectively. The biological oxygen demand (BOD) and chemical oxygen demand (COD) were 18400 mg L^{-1} and 26350 mg L^{-1} respectively, which are well above the permissible limits for discharge into water and on land (2,100 mg L^{-1} for dissolved solids and 200 mg L^{-1} for suspended solids), as it may pollute the water bodies and lands if discharged unscientifically.

Primary spentwash contains all the essential plant nutrient elements in appreciable quantities of nitrogen, phosphorus and potassium content was 0.17, 0.031 and 1.06 per cent while the calcium, magnesium and sodium content was 1759.0, 1285.0, 1093 mg L^{-1} respectively. The average concentration of iron, manganese, zinc and copper was 21.9, 6.61, 2.5 and 4.03 mg L^{-1} respectively. Thus it can be used as liquid fertilizer. Kulkarni *et al*. (1987) opined that spentwash was all the nutrients and also organic matter and hence can be used as liquid organic manure.

5.2 Studies on utilization of distillery spentwash for reclamation of sodic soils

5.2.1 Green House Experiment – I: Effect of raw spentwash application on reclamation of sodic and calcareous sodic soil

5.2.1.1 Effect of different levels of raw spentwash and gypsum application on soil pH

Soil pH differed significantly due to application of different quantities of raw spentwash in both sodic and calcareous sodic soil (Table 4.2, Fig. 5.1 & 5.6). With increase in levels of raw spentwash there was progressive decrease in soil pH. Significant decrease in soil pH was noticed in treatment receiving 5.0 lakh liters ha^{-1} at 60 days after application which was on par with treatment receiving 7.5 lakh liters ha^{-1}. Gypsum applied @100% GR also reduced the soil pH to a greater extent and it was on par with raw spentwash applied at 2.5 lakh liter ha^{-1}. The findings are in line with Sharma *et al.* (1981) who reported that the soil pH reduced from 10.4 to 8.04 due to gypsum application. The reduction in soil pH was attributed to displacement of exchangeable Na by the calcium ion of gypsum and subsequent formation of sodium sulphate which get leached out of soil through drainage in the pots. Similar reduction in pH of sodic soil due to the application of gypsum was reported by Srinivasa (1995), Ramappa Jakanur (1998) and GuruPrasad (2005).

Decrease in soil pH in both the soils was attributed to acidic nature of raw spentwash (pH 4.1) which might have solubilized the native calcium carbonate and released free calcium ions and other calcium bearing minerals to the soil. In addition the spentwash has calcium to an extent of 2600 mg L^{-1}. There was marginal and minimum reduction in soil pH at 90 and 120 days after application compared to 60 days. The decrease in soil pH was more pronounced in Calcareous sodic soil compared to sodic soil. This was due to acidic nature of raw spentwash which might have solubilized the native free lime thus facilitating the release of Ca+Mg in free ionic forms and these ions have replaced the Na^+ on the exchange complex. Also, the substantial quantity of sulfur present in raw spentwash, might have solubilised the $CaCO_3$ thus decreasing the pH of soil. Results obtained in this study are in conformity with the findings of Mohammed Haroon and Subash Chandra Bose (2004) and Mahendra (2007).

5.2.1.2 Effect of different levels of raw spentwash application on electrical conductivity of soil

Application of different levels of raw spentwash had significant influence on electrical conductivity of both the soils (Table 4.2 Fig. 5.2 & 5.7). Increased levels of raw spentwash application significantly increased electrical conductivity of both the soils and highest electrical conductivity value was noticed in treatment receiving 10.0 lakh liters

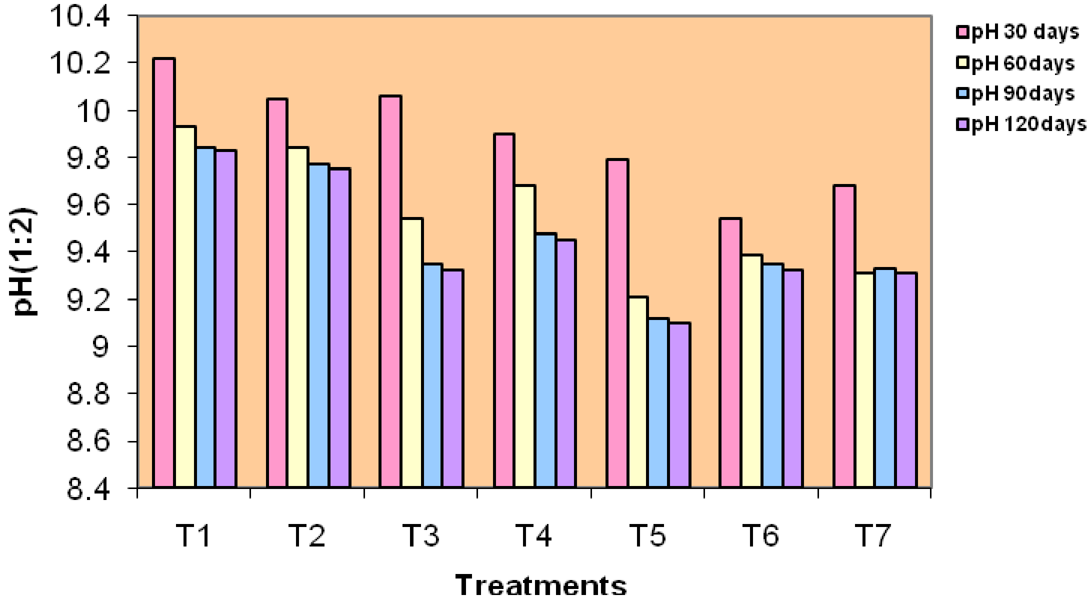

Fig. 5.1 : Effect of raw spentwash and gypsum application on pH of sodic soil

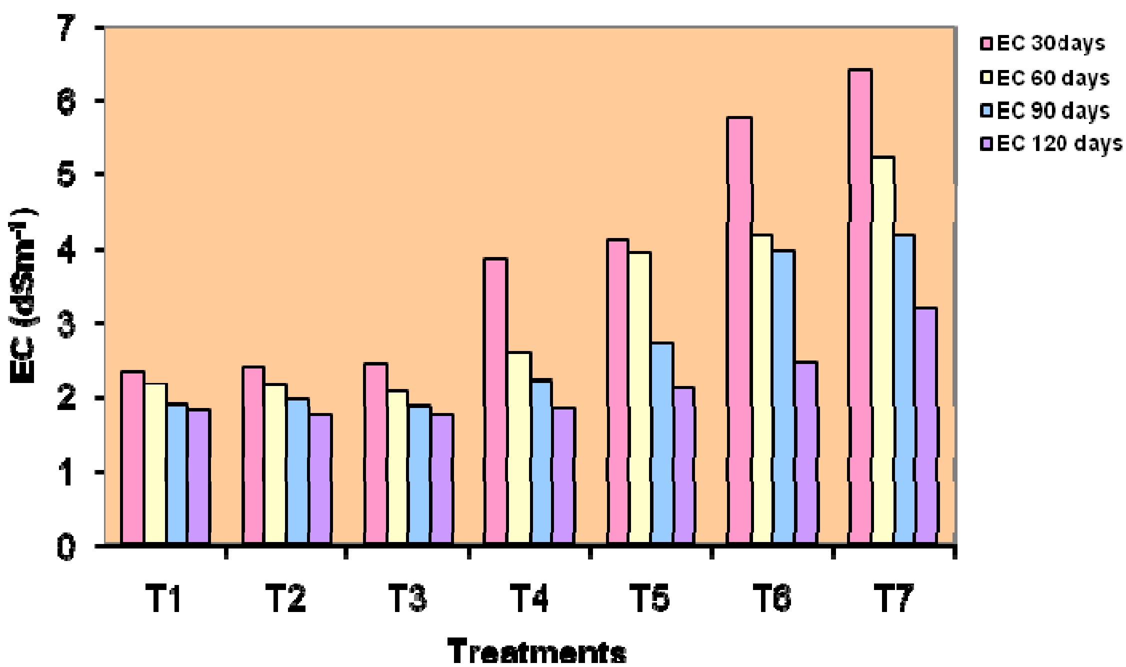

Fig. 5.2 : Effect of raw spentwash and gypsum application on electrical conductivity of sodic soil

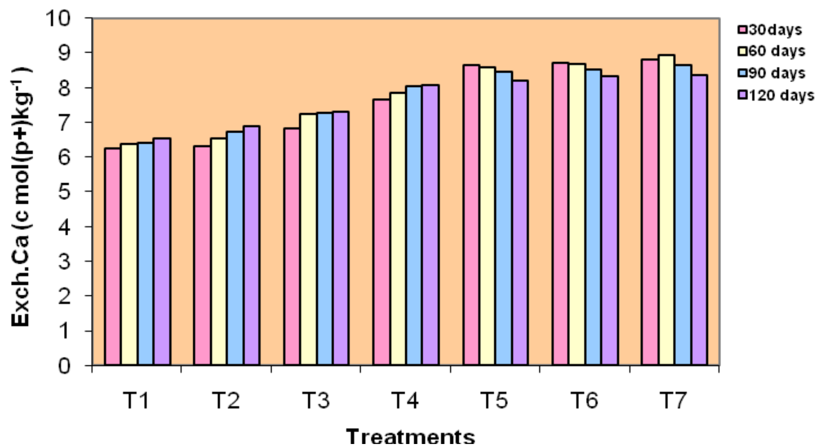

Fig. 5.3 : Effect of raw spentwash and gypsum application on exchangeable Ca content of sodic soil

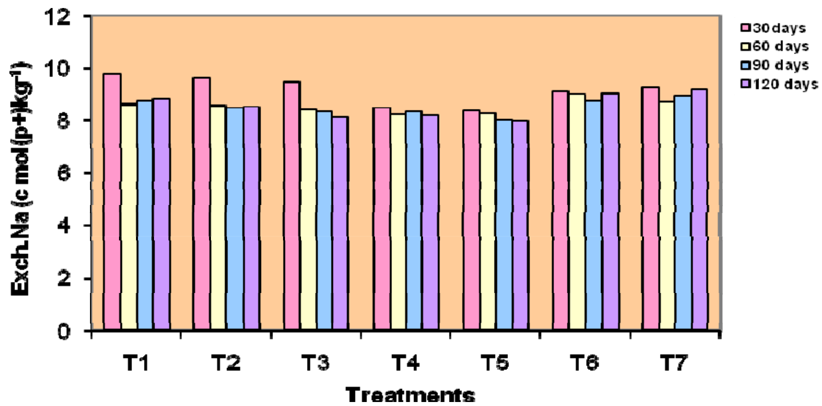

Fig. 5.4 : Effect of raw spentwash and gypsum application on exchangeable Na content of sodic soil

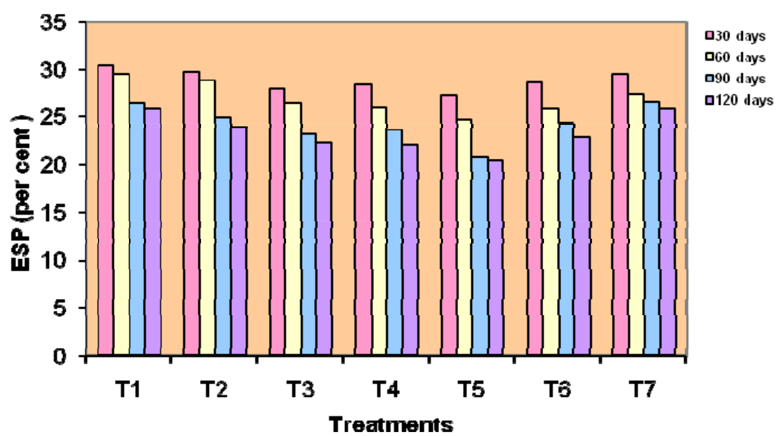

Fig. 5.5 : Effect of raw spentwash and gypsum application on ESP of sodic soil

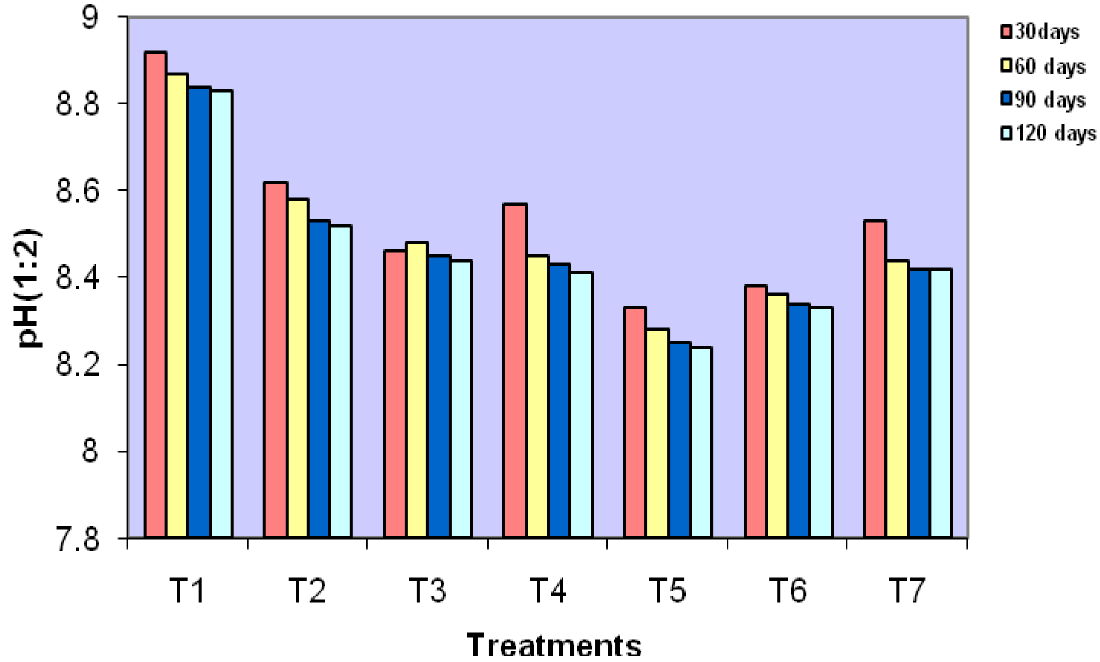

Fig. 5.6 : Effect of raw spentwash and gypsum application on pH of calcareous sodic soil

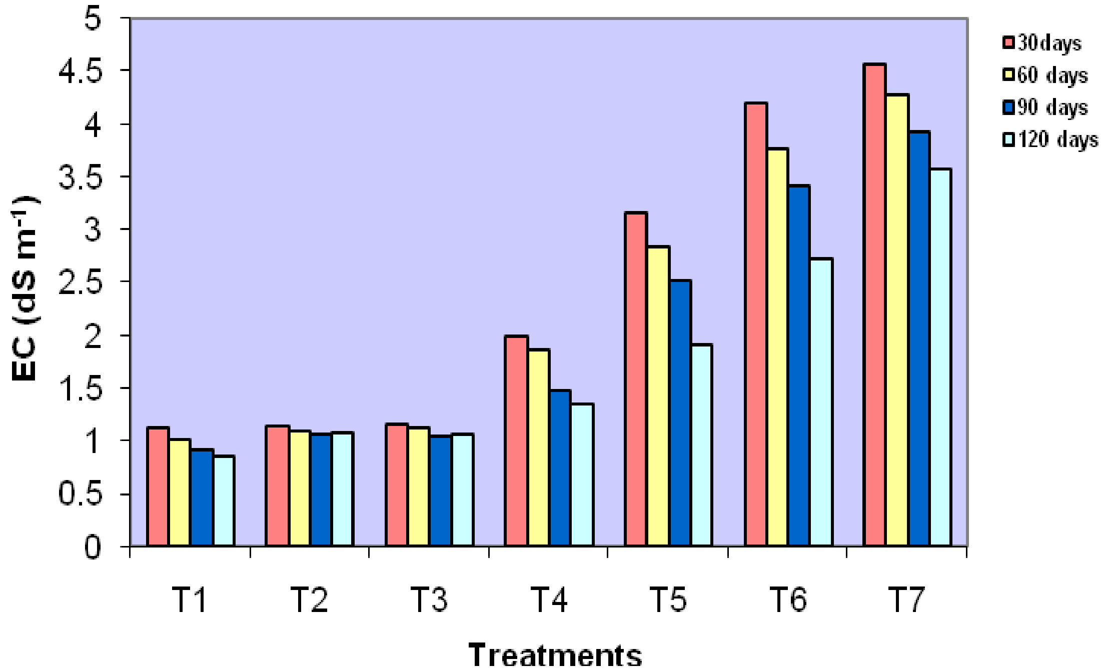

Fig. 5.7 : Effect of raw spentwash and gypsum application on Electrical conductivity of calcareous sodic soil

ha^{-1}. Application of raw spentwash significantly increased the electrical conductivity of soil compared to gypsum treatments. Significantly highest soil electrical conductivity was recorded in T_7 receiving 10 lakh liters of spentwash per hectare followed by T_6 receiving 5.0 lakh liters ha^{-1} of spentwash per hectare and was significantly superior over other treatments. Application of gypsum slightly increased the soil EC but was not significant compared to raw spentwash application. The increase in the soluble salt content in the gypsum amended pots might be attributed to the chemical reactions of gypsum in the soil rendering them to more soluble sulphate of sodium. The presence of more soluble salt resulted in higher conductivity values in gypsum treated pots.

There was no much variation between the two soils with respect to electrical conductivity values. However, there was a gradual reduction in soluble salt concentration with increase in the number of days after application of raw spentwash and gypsum which may be due to the leaching of soluble salts through drainage holes provided. However at 120days after application highest soil EC was recorded in T_7 receiving 10 lakh liters of ha^{-1} spentwash per hectare followed by T_6 receiving 5.0 lakh liters $ha^{-1}$of spentwash per hectare and was found superior over application of gypsum @100% GR. Similarly in calcareous sodic soil, highest EC was noticed in T_7 receiving 10 lakh liters ha^{-1} of spentwash per hectare as compared to gypsum @100% GR. The decrease in conductivity values in each treatment over a period of time may be attributed to leaching of salts through drainage during reclamation. Chauhan and Tripathi (1983) reported that application of gypsum followed by leaching markedly reduced the electrical conductivity to normal levels in alkali soil. Similar results were also reported by Srinivasa (1995) and Guruprasad (2005).

Increased EC values in treatments involving spentwash may be due to the addition of soluble salts through raw spentwash which recorded electrical conductivity of 17.0 dS m^{-1}. Significant increase in soluble salts concentration of soil due to high soluble salt content of raw spentwash was only temporary as drainage provided to these soils, leached the accumulated salts. Results obtained in this study are in close conformity with the findings of Anon. (2005). High amount of soluble salts present in spentwash on direct application to soil at higher levels creates the problem of salinity (Patil *et al.,* 2000).

Suma (2006) reported that one time application of distillery spentwash at 1000 m^3 ha^{-1} and 1500 m^3 ha^{-1} significantly increased the salt content of soil and was above the threshold level rendering these soils into saline soils.

5.2.1.3 Effect of different levels of raw spentwash and gypsum application on exchangeable Ca+Mg content of soil

Data on exchangeable Ca+Mg content of soil for two different kinds of sodic soils showed a remarkable and gradual increase in exchangeable Ca+Mg content with increased levels of raw spentwash at 30days after application (Table 4.2, Fig. 5.3 & 5.8). Increased application of raw spentwash at 5.0 lakh liters ha^{-1} increased exchangeable Ca+Mg compared to gypsum treatments. This might be due to enhanced dissolution of free $CaCO_3$ upon application of higher quantity of raw spentwash. During distillation of molasses, lime is added in distilleries to maintain the pH, which ultimately accumulates in spentwash and becomes available in soils upon its application. Increased Ca+Mg content in both the soil was due to the presence of 2600 mg L^{-1} of Ca and 1700 mg L^{-1} of Mg in raw spentwash that was added to the soils in different quantities which helped in better replacement of exchangeable sodium by Ca ions. Further, the acidic nature of raw spentwash (pH 4.11) might have solubilized native free lime which released Ca+Mg in free ionic forms which might have also contributed for increased Ca+Mg on exchange sites with the replacement of exchangeable sodium. Similar observations were also reported by Santiago Mahimaraja and Nanthi Bolan (2000) and Taluk Medeiros (1989) and Baskar *et al*., (2003) that application of raw spentwash increased the Ca and Mg contents in red yellow medium textured latosol.

After 60days of application, there was slight decrease in exchangeable Ca+Mg contents in both the soils this may be due to leaching of Ca+Mg salts from the soil along with sodium**.** Comparison between calcareous and other soil with respect to exchangeable Ca+Mg contents indicated that calcareous sodic soil recorded higher Ca+Mg than Sodic soil. The results obtained are in conformity with the findings of Mahendra (2007).

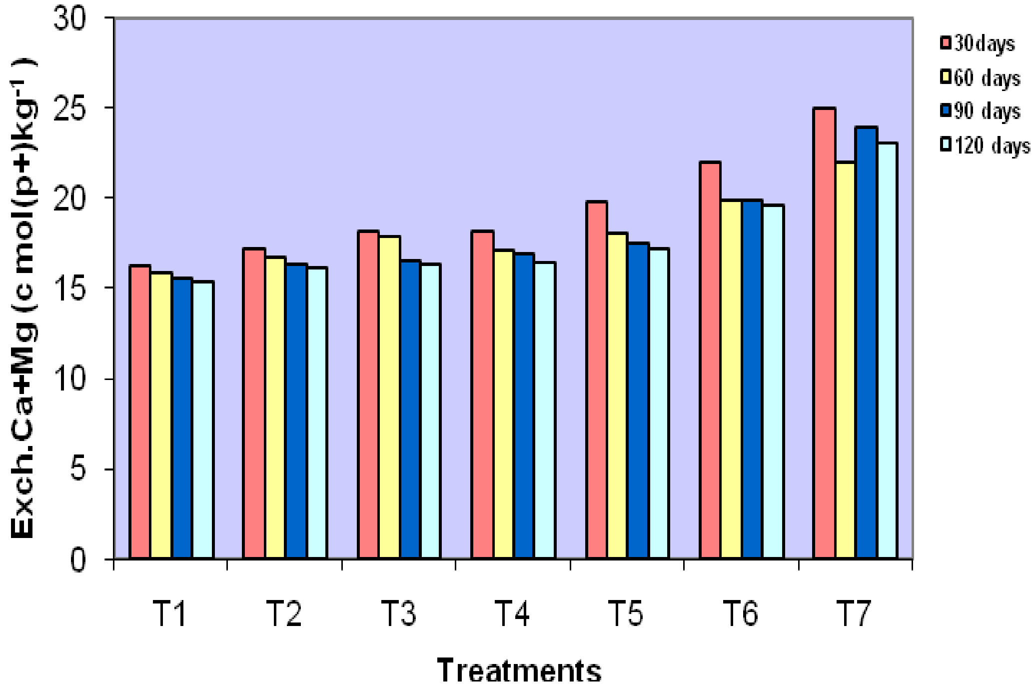

Fig. 5.8 : Effect of raw spentwash and gypsum application on exchangeable Ca+Mg content of calcareous sodic soil

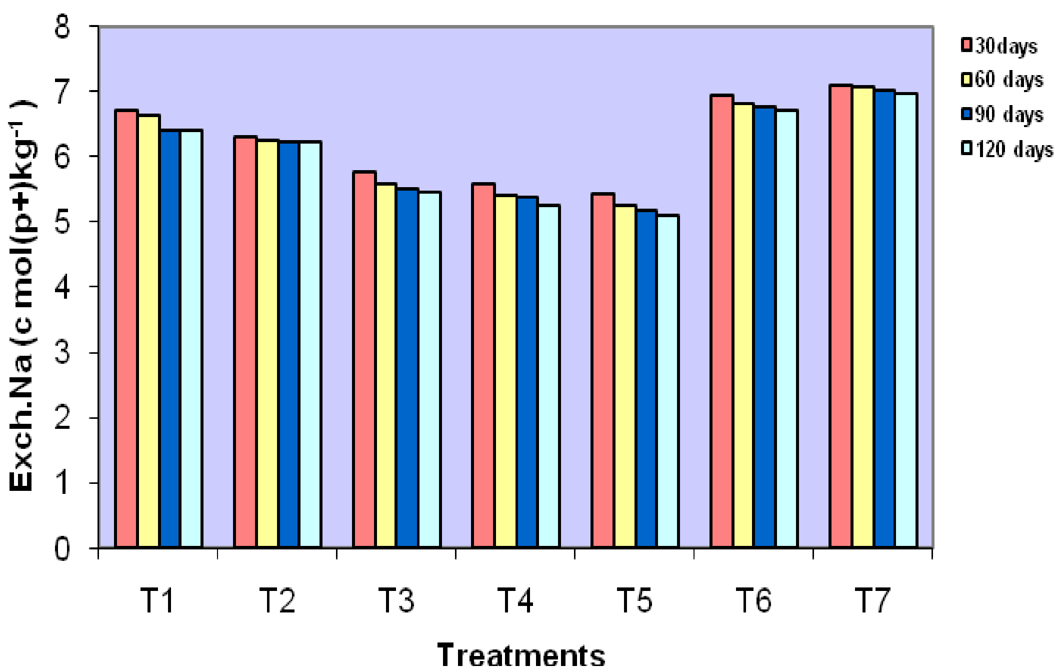

Fig. 5.9 : Effect of raw spentwash and gypsum application on exchangeable Na content of calcareous sodic soil

5.2.1.4 Effect of different levels of raw spentwash and gypsum application on exchangeable sodium content of soil

Application of raw spentwash at different quantities significantly decreased the exchangeable sodium content of both the soil (Table 4.3, Fig.5.4 &5.9). The lowest exchangeable sodium content of both the soil was recorded in treatment T_5 which received 5.0 lakh liters ha^{-1} and was on par with T_6 (7.5 lakh liters ha^{-1}).

The results are in accordance with the findings of Rachhpal Singh *et al.,* (1980) who reported that application of concentrated form of spentwash helped in greater exchange of sodium by calcium and subsequent leaching with good quality water replaced the sodium from the exchange sites. Similar observations were also reported by Mohammed Harron and Subash Chandra Bose (2004) .With the increase in days after application of raw spentwash, there was gradual decrease in reduction of exchangeable sodium after 60days but there was sudden decrease in exchangeable sodium content at 30 and 60 days after application. Similar observations were also reported by Mahendra (2007).

5.2.1.5 Effect of different levels of raw spentwash and gypsum application on ESP of soil

Application of raw spentwash at different quantities significantly reduced the ESP of both the soils (Table 4.3, Fig. 5.5 & 5.10 and Plate 4 & 5). The lowest exchangeable sodium percentage in both the soils was recorded in treatment T_5 which received 5.0 lakh liters ha^{-1} and T_6 (7.5 lakh liters ha^{-1}).

Hence T_5 RSW @ (5.0 lakh liters ha^{-1}) treatment considered optimum for practical purpose for reducing the ESP to a desired level under field conditions. The results are in accordance with the findings of Rachhpal Singh *et al.* (1980), Mohammed Haroon and Subash Chandra Bose (2004), Rajakunnu *et al*. (1996) and Valliappan (1998).With the increase in days after application of raw spentwash there was gradual reduction in ESP.

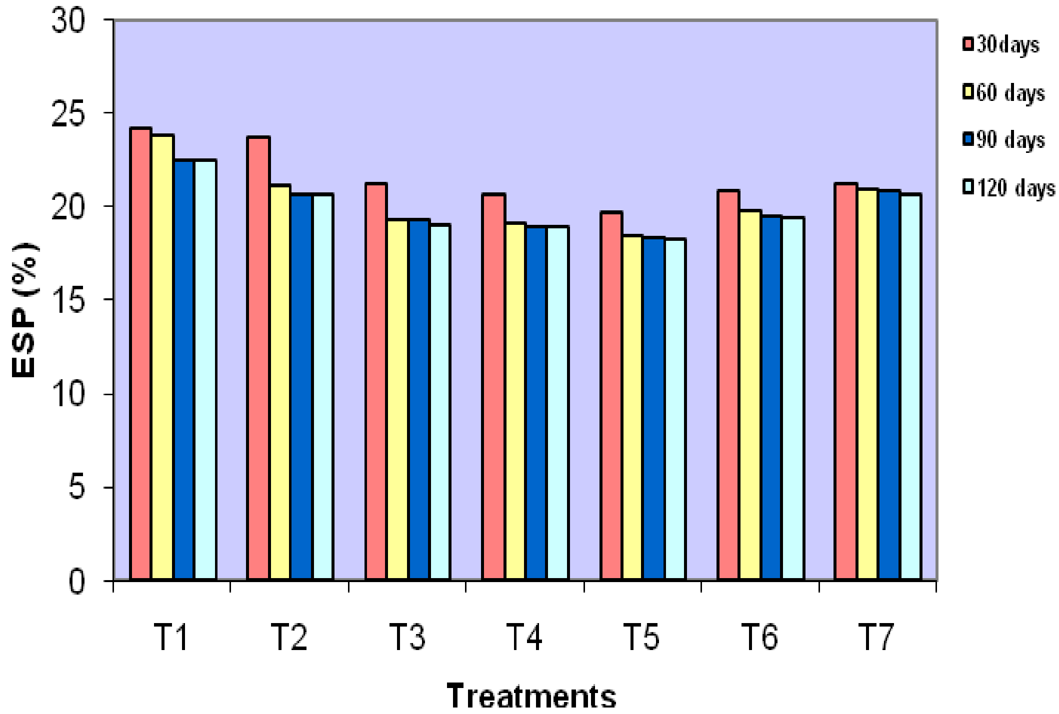

Fig. 5.10 : Effect of raw spentwash and gypsum application on ESP of calcareous sodic soil

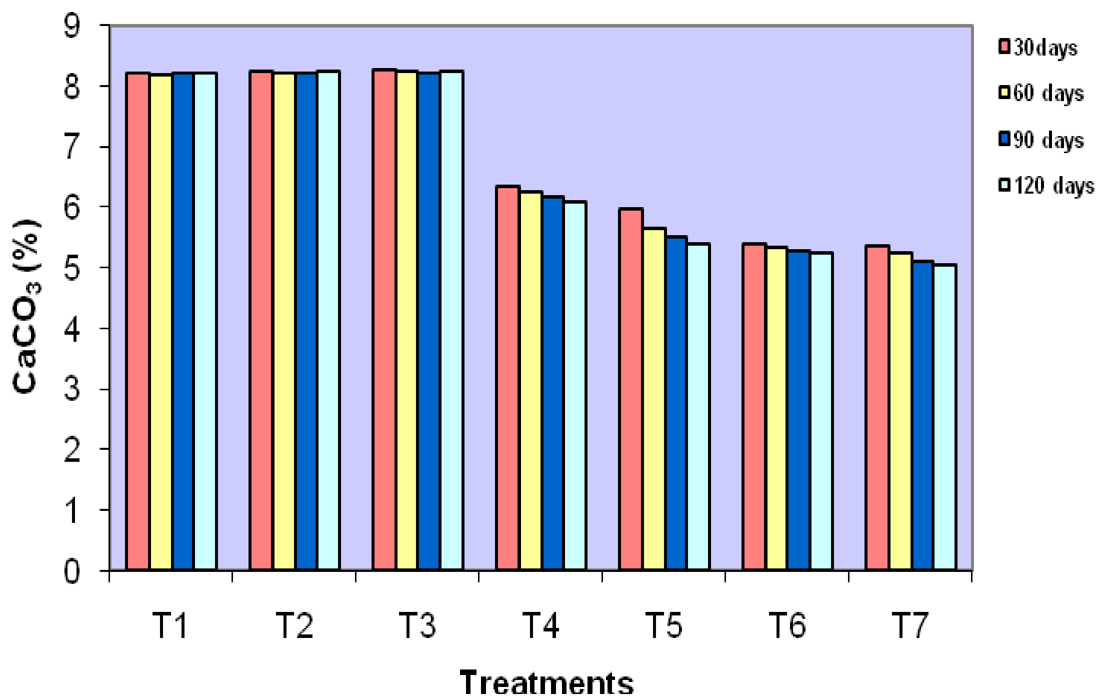

Fig. 5.11 : Effect of raw spentwash and gypsum application on Lime content of calcareous sodic soil

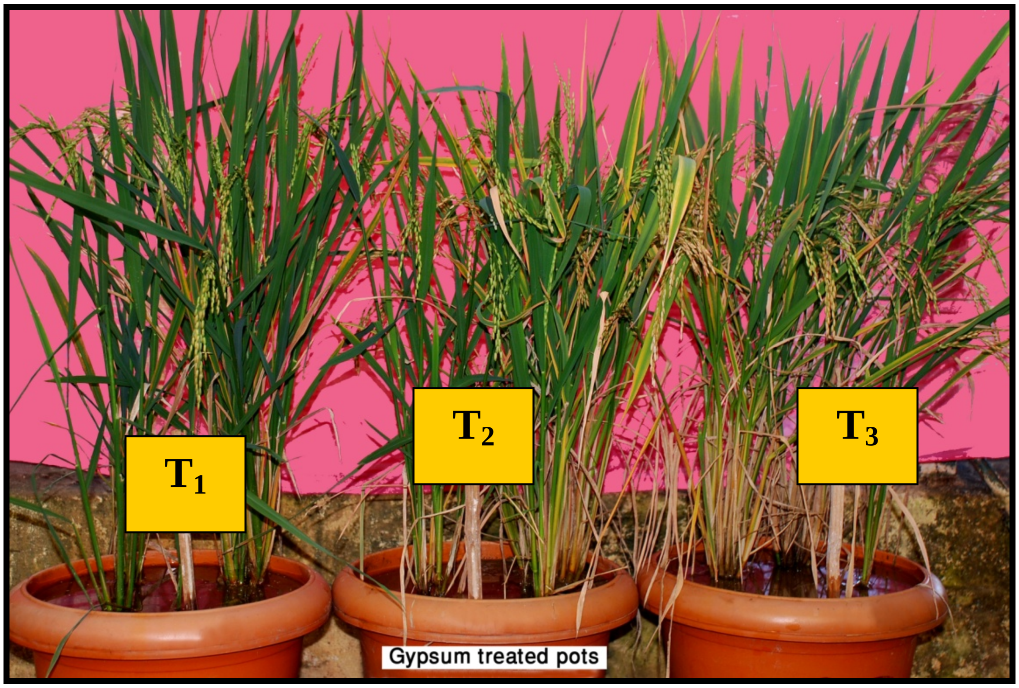

Plate 4 : Effect of different levels of gypsum on growth of paddy
(T_1: Gypsum @ 50% GR , T_2: Gypsum @ 75% GR, T_2: Gypsum @ 100 % GR)

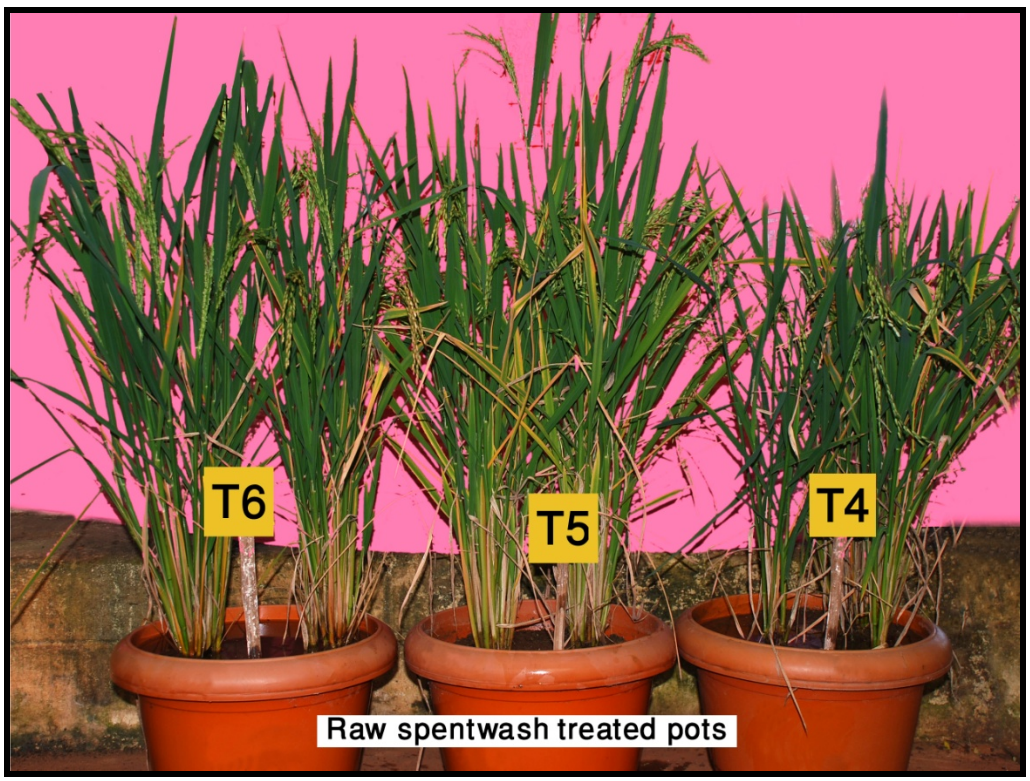

Plate 5 : Effect of different levels of raw spentwash on growth of paddy
(T_4: RSW @ 2.5 lakh liters ha^{-1}, T_5: RSW @ 5.0 lakh liters ha^{-1} , T_4: RSW @ 7.5 lakh liters ha^{-1})

5.2.1.6 Effect of different levels of raw spentwash and gypsum application on $CaCO_3$ content of soil

Application of raw spentwash at different quantities significantly decreased the $CaCO_3$ content of soil (Table 4.3, plate 5.11). The lowest $CaCO_3$ content for both the soils was recorded in treatment T_7 which received 10.0 lakh liters ha^{-1} followed by T_6 (7.5 lakh liters ha^{-1}). The decrease in free lime content of soil with increased levels of raw spentwash might be due to greater solublization of alkaline earth carbonates brought about by acidic nature of raw spentwash. The results are in conformity with the findings of Anonymous (2002) for calcareous soils of Somayannur series in Tamil Nadu, Subba Rao *et al.* (1972) and Mahendra (2007).

5.2.1.7 Effect of different quantities of spentwash and gypsum application on chemical composition of leachate.

Increasing quantities of raw spentwash application significantly increased the pH, EC, HCO_3^-, Cl^-, SO_4^{2-},Ca^{2+}, Mg^{2+} and Na^+, in leachate samples (Table 4.4 to 4.7, Fig. 5.12 to 5.16). Similar observations were made by Devarajan and Oblisami (1995) and Malathi (2002).

In general, pH and EC of the leachate collected at different intervals increased which might be due to leaching of salts, which increased the pH of leachate. Salt concentration in the leachate increased with increasing levels of raw spentwash. Application of raw spentwash @10.0 lakh liters ha^{-1} recorded significantly higher values compared to gypsum amended plots. Among the anions, HCO_3^-> Cl^- >SO_4^{2-} leached in higher quantities. In general, anions concentration increased with greater quantity of raw spentwash application and it decreased with increase in different days after application. Among cations Na^+ leached was more compared to Ca^{2+} and Mg^{2+} as it is monovalent, retention on exchange site is less compared to Ca^{2+} and Mg^{2+} which are being divalent, get strongly adsorbed on clay surface. A similar result of increased salt content in ground water near lagoon sites in most of the distilleries was noticed by Joshi *et al*. (1994). Husain *et al*. (2003), Anilkumar *et al*. (2003), Malathi (2002) and Suma (2006) who noticed the leaching of anions and cations from soil profile with higher quantities of

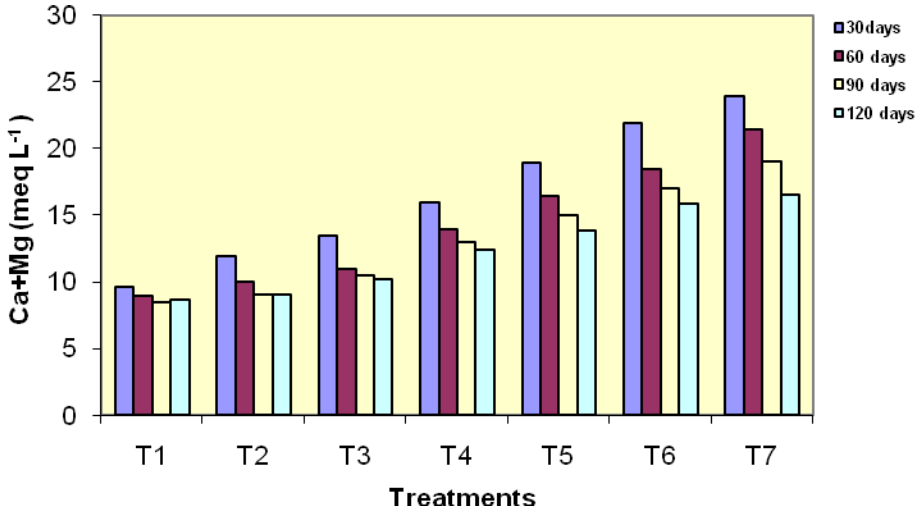

Fig. 5.12 : Effect of raw spentwash and gypsum application on Ca+Mg content of leachate from sodic soil

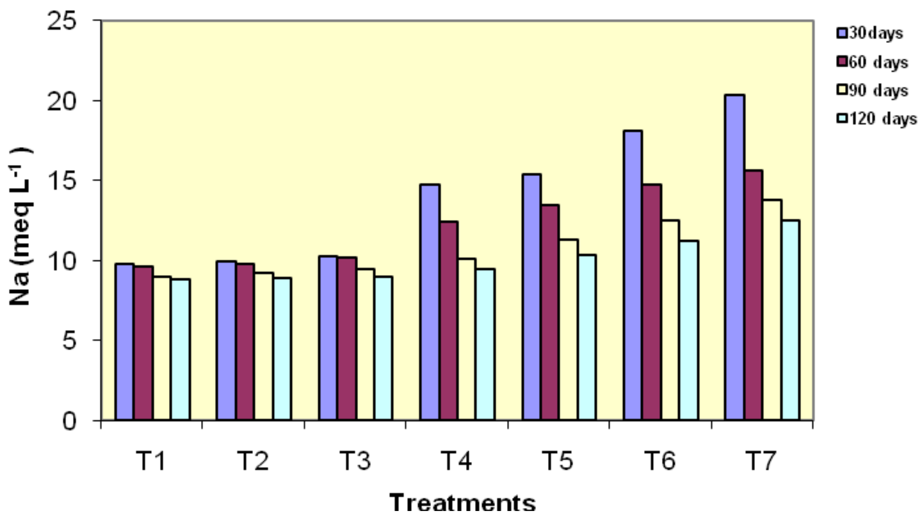

Fig. 5.13 : Effect of raw spentwash and gypsum application on Sodium content of leachate from sodic soil

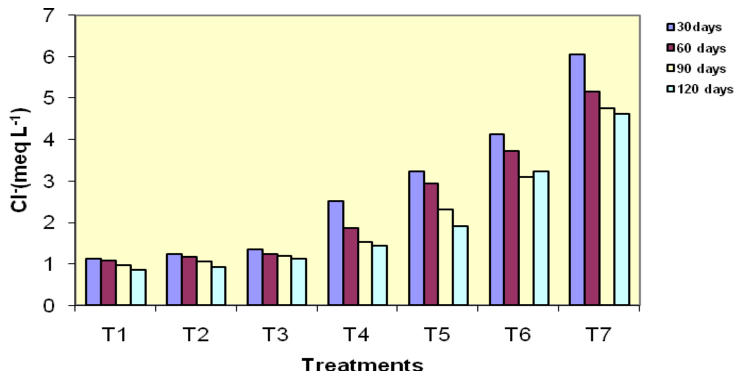

Fig. 5.14 : Effect of raw spentwash and gypsum application on Chloride content of leachate from sodic soil

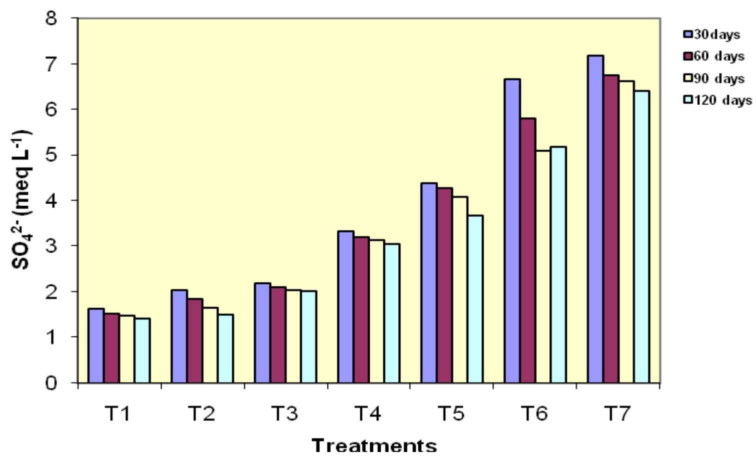

Fig. 5.15 : Effect of raw spentwash and gypsum application on Sulphate content of leachate from sodic soil

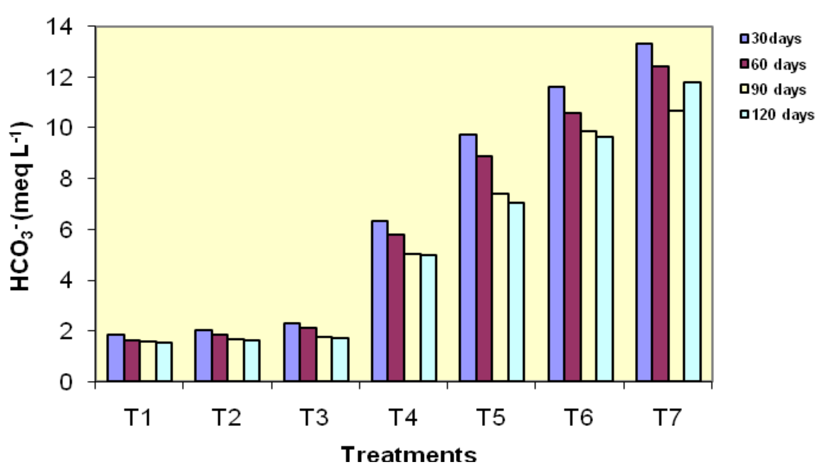

Fig. 5.16 : Effect of raw spentwash and gypsum application on Bicarbonate content of leachate from sodic soil

spentwash. Concentration of these cations and anions in the leachate decreased gradually upto 120 days after application.

5.2.2 Field Experiment –I

5.2.2.1 Effect of raw spentwash application on growth and yield of paddy

5.2.2.1.1 Growth and yield parameters.

Application of raw spentwash significantly influenced the growth and yield parameters of paddy (Table 4.8). Irrespective of the levels, raw spentwash significantly influenced the growth and yield parameters like plant height, number of tillers, number of seeds per panicle and thousand grain weight compared to gypsum amended plots. This might be due to the fact that raw spentwash besides a source of calcium as an amendment is also a good source of all the essential nutrients which are required for plant growth. Results of increased growth and yield parameters were also reported by Devarajan *et al.,* (1994) in ground nut crop, Patil *et al.,* (2000) and Mahendra (2007) in sunflower crop due to application of various amendments.

5.2.2.1.2 Grain and straw yield.

There was significant increase in grain yield of paddy due to the effect of raw spentwash application (Table 4.8, Fig. 5.17 & Plate 6, 7, 8, 9 &10). Raw spentwash application has resulted in higher grain yield mainly due to its nutritional effects, in addition to improvement in physical and chemical properties of the soil. The results indicated that application of raw spentwash @ 5.0 lakh liter ha^{-1} (T_4) recorded significantly higher grain yield followed by T_5 (raw spentwash 7.5 lakh liter ha^{-1}). Application of gypsum @ 100% GR recorded lesser yield compared to T_4 and T_5 but was on par with T_3 (raw spentwash @ 2.5 lakh liter ha^{-1}). From the results it was evident that gypsum application improved the soil properties by decreasing pH and ESP but could not help the crop with better nutrition and hence lesser yield compared to raw spentwash application.

Among the treatments, raw spentwash application was found more effective in increasing the straw yield. In addition to calcium the raw spentwash used in the present

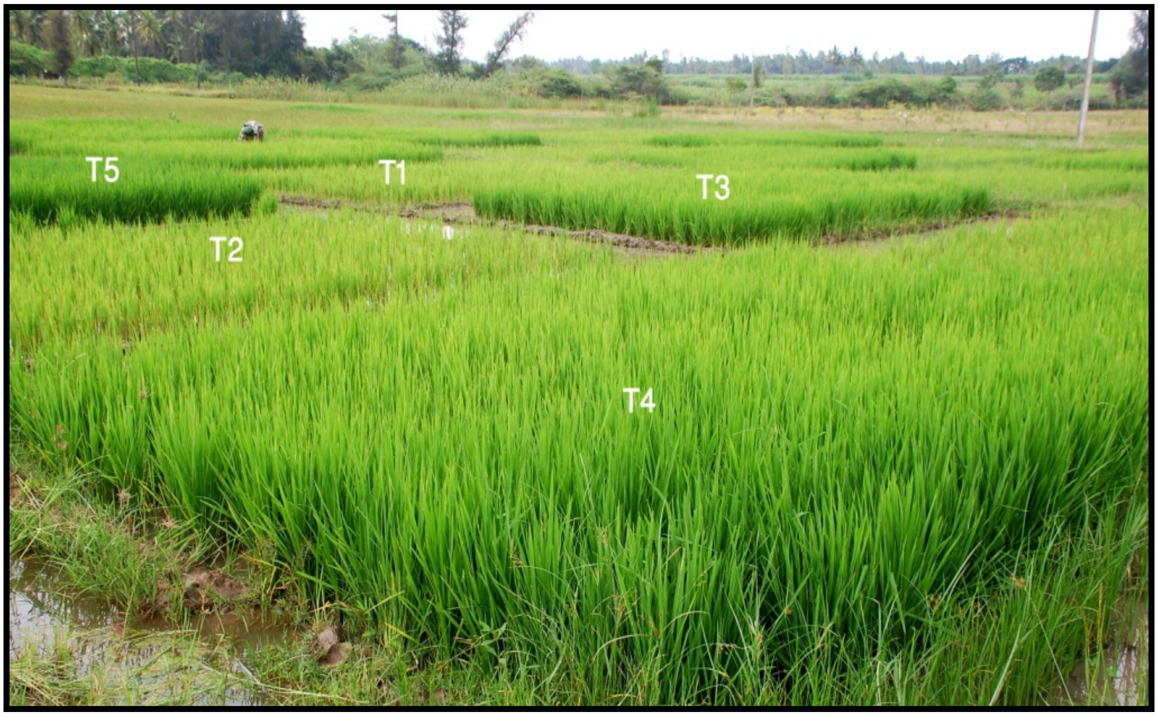

Plate 6 : General view of the field experiment at tillering stage

Plate 7 : General view of the field experiment at maturity

Plate 8 : Paddy crop with Raw spentwash @ 2.5 lakh liters ha^{-1} (T_3)

Plate 9 : Paddy crop with Raw spentwash @ 5.0 lakh liters ha^{-1} (T_4)

Plate 10 : Paddy crop with Raw spentwash @ 7.5 lakh liters ha^{-1} (T_5)

investigation contained enough sulphur which upon oxidation acidified the medium and solubilised the native calcium carbonate reserves of the soil. The released calcium and magnesium replaces the sodium on the exchange complex which inturn improved the physical and chemical properties of soil for better uptake of plant nutrients.

The reason for increased straw yield in spentwash applied plots might be due to higher soil available nitrogen in these plots. The effect of raw spentwash application on the straw yield of paddy followed the similar trend as that observed under grain yield. Significantly higher yields were obtained due to application of raw spentwash @ 7.5 lakh liters ha^{-1}. Addition of more nutrients through raw spentwash resulted in the higher grain and straw yield. Higher grain and straw yield in paddy could be attributed to better total uptake of essential nutrients and its translocation to economic parts as well as improvement in yield attributing characters like length of panicle, number of panicles, number of seeds per panicle, and thousand grain weight.

Bhakiyathu Saliha *et al.* (2004) reported that application of raw spentwash at 1.25 lakh litres ha^{-1} helped in reducing the pH and ESP of the soil to transfer limits besides enhancing soil nutrient status. The results of the present investigation are in agreement with Geetha *et al.* (2007) who reported that on an average, there was 20-25% increase in rice yield in reclaimed soil treated with spentwash when compared to non-reclaimed one and similar results were also observed by Balasubramanian *et al.* (2007) that the application of spentwash significantly improved the rice crop growth and yield.

5.2.2.1.3 Effect of raw spentwash on nutrient uptake by paddy

5.2.2.1.3.1 Total nutrient uptake by paddy

The uptake of nitrogen, phosphorus and potassium by the crop at the time of harvest due to raw spentwash application during reclamation of sodic soil are presented in (Table 4.9 & Fig.5.18) Irrespective of the levels of raw spentwash, nutrient uptake was comparatively high in spentwash treatments. This could be attributed to the fact that, raw spentwash besides acting as an amendment for reclamation of sodic soil also provides all the essential nutrients in sufficient quantities for better uptake. Results of enhanced uptake of nutrients due to the application of raw spentwash was reported by Gomez (1996), Korndorfer and Anderson (1993) and Mahendra (2007). Highest nitrogen uptake in raw spentwash applied plots compared to gypsum application. Application of raw spentwash @ 7.5 lakh liters ha^{-1} recorded significantly higher uptake compared to gypsum @100% GR and T_1 (rec. NPK without amendment). Chauhan (1995) reported that application of gypsum increased the uptake of N, P, K and Zn by rice crop in sodic soil. The highest nitrogen uptake is due to more availability of soil available nitrogen due to higher rate of application of raw spentwash. Total nitrogen uptake by paddy increased with increasing doses of raw spentwash. Nitant and Dargan (1974) observed higher nitrogen uptake and N content in paddy leaves due to application of organic mannures in alkali soils.

There was significant increase in the phosphorus uptake by paddy crop due to application raw spentwash during reclamation of sodic soil. Significant increase in P uptake was noticed in T_5 (raw spentwash @ 7.5 lakh liters ha^{-1}) which was on par with T_4 (5.0 lakh liters ha^{-1}) recording 18.06 kg $ha^{-1.}$ Lower P uptake was recorded in T_3 (2.5 lakh liters ha^{-1}) compared to T_4 & T_5 but was on par with the treatment T_2 (Gypsum @100%GR+rec.NPK). The higher availability of phosphorus in soils of raw spentwash treated plots has contributed for higher uptake by the crop. Decomposition of high organic matter load applied through spentwash helped in availability of phosphorus due to solubilising effect of certain organic acids and Carbon dioxide produced during decomposition. Liberated phosphorus present in the raw spentwash upon decomposition in the soil will contribute for higher available phosphorus and more crop uptake. At higher N/P ratio, better utilization of applied P in the presence of higher N, must have contributed for more P uptake. The greater mobilization of P in the presence of N was reported by Steer and Hocking (1983).

Potassium uptake by paddy was significantly increased due to raw spentwash application during reclamation of sodic soil. Increased application of raw spentwash significantly increased the K uptake compared to the treatments receiving gypsum and recommended dose of NPK. K uptake was significantly highest in T_5 receiving raw spentwash @ 7.5 lakh liters ha^{-1} compared to T_2 (Gypsum @100%GR) and was on par

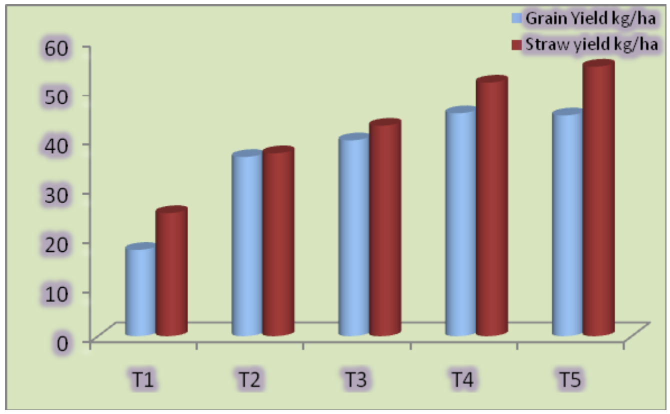

Fig. 5.17 : Effect of raw spentwash and gypsum application on grain & straw yield of paddy at VC farm Mandya

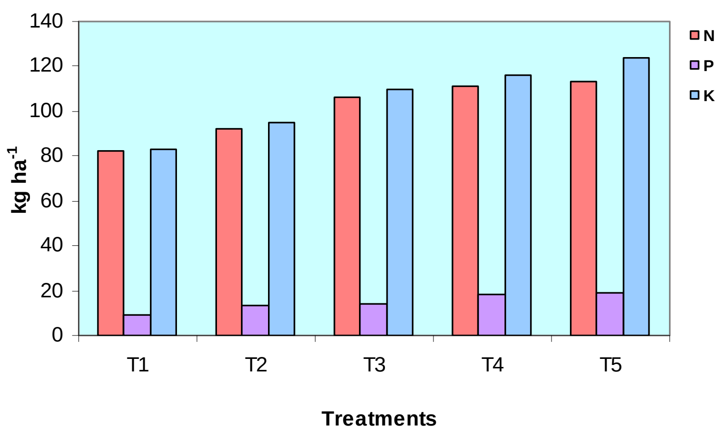

Fig. 5.18 : Effect of raw spentwash and gypsum application on nitrogen, Phosphorus and potassium uptake by paddy at VC farm Mandya

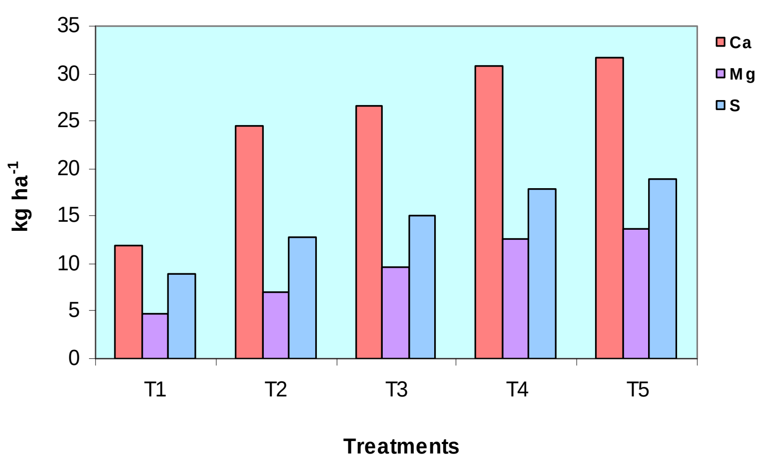

Fig. 5.19 : Effect of raw spentwash and gypsum application on calcium, magnesium and sulphur uptake by paddy at VC farm Mandya

with T_4 (5.0lakh liters ha^{-1}) and T_3 (2.50 lakh liters ha^{-1}). Higher uptake of K in raw spentwash amended plots might be due to higher availability of K recorded in raw spentwash amended treatments.

Similarly Calcium, magnesium, sulfur and micro-nutrient uptake was also found highest in raw spentwash amended plots compared to gypsum (Table 4.9 & Fig.5.18). Highest nutrient uptake in raw spentwash treatments might be attributed to favorable soil physical and chemical conditions that might have increased the availability of nutrients with application of raw spentwash which has high organic load. The increase in uptake of nutrients may also be due to higher nutrient content coupled with better vegetative growth in these treatments. Results of enhanced uptake of nutrients due to the application of raw spentwash was reported by Gomez (1996), Korndorfer and Anderson (1993) and Mahendra (2007).

5.2.2.1.4 Soil properties

5.2.2.1.4.1 Soil pH

Soil pH differed significantly due to raw spentwash application at flowering stage, while the decrease in soil pH after the harvest of crop was not significant (Table 4.10 Fig.5.20). During tillering and flowering stages of paddy, the reduction in soil pH was maximum in T_4 (5.0 lakh liters ha^{-1}) followed by T_5 (7.5 lakh liters ha-^{1}) and were significantly superior over application of gypsum @ 100% GR and treatment receiving RSW @ 2.5 lakh liter ha^{-1} and these two treatments were on par with each other.

The reduction in soil pH was attributed to displacement of exchangeable Na by the calcium ion of gypsum and subsequent formation of sodium sulphate which get leached out of soil through drainage. Anand Swarup (1991) studied the effects of gypsum with green manure and farm yard manure on nutrition of rice in a sodic soil with pH 10.2. Application of gypsum markedly decreased the pH to 9.2 after three months, while combination of gypsum with green manure and farm yard manure reduced it to 9.0 and ESP reduced from 86 to 28 per cent. Rice responded significantly to Zinc in combination with gypsum. Chauhan (1995) observed that pH decreased from 10.5-8.6 with the application of gypsum @ 50per cent GR for alkali soils of Faizabadh in Uttar Pradesh. Similar observations were made by Rajukannu *et al.* (1996) in alkali soils of Tamil Nadu and they reported that application of 5 lakh liters of raw spentwash was found to be optimum for the soil having pH range from 8.5-10.0. Many researchers reported reduction in soil pH with application of raw spentwash (Rachhpal Singh *et al.* (1980). Bhakiyathu Saliha *et al.* (2004) reported that application of raw spentwash at 1.25 lakh litres ha^{-1} helped in reducing the pH and ESP of the soil to safer limits besides enhancing soil nutrient status. Sharmila Rahale *et al.* (2007) found that the application of spentwash to sodic soil decreased the soil pH to a range from 9.0 - 9.8 to 8.1 - 8.9. Bhakiyathu Saliha *et al.* (2007) studied the effect of one time application of raw spentwash @ 125 m^3 ha^{-1} for reclamation of sodic soils and the results revealed that the average pH of soil samples decreased from 9.10 to 8.35.

5.2.2.1.4.2 Electrical Conductivity

The electrical Conductivity of soil differed significantly due to raw spentwash application upto flowering stage, while decrease in soil pH after the harvest of crop was not significant (Table 4.10 Fig.5.21). During tillering and flowering stages of paddy the soil EC was maximum in T_4 (5.0 lakh liters ha^{-1}) followed by T_5 (7.5 lakh liters ha-^{1}) and significantly superior over application of gypsum @ 100% GR and T_3 (RSW@ 2.5 lakh liter ha^{-1}) and the effect of both the treatments were on par with each other. There was significant decrease in electrical conductivity compared to raw spentwash application; however there was a slight increase in EC of soil due to replacement of exchangeable sodium by calcium ions of gypsum with subsequent formation of soluble sodium sulphate which will be leached out of soil through drainage. Significant increase in electrical conductivity in raw spentwash amended plots may be attributed to high salt content in raw spentwash added to soil during reclamation process, resulting in slight build up. But the extent of build up was below the critical limit (4 dS m^{-1}).There was increasing electrical conductivity with increased levels of raw spentwash levels. Also acidic nature and fairly good amount of calcium of raw spentwash which helped in solublization of free lime which replaced the sodium on exchange complex form soluble sodium salts might have contributed for increase in electrical conductivity of soil. The results are in

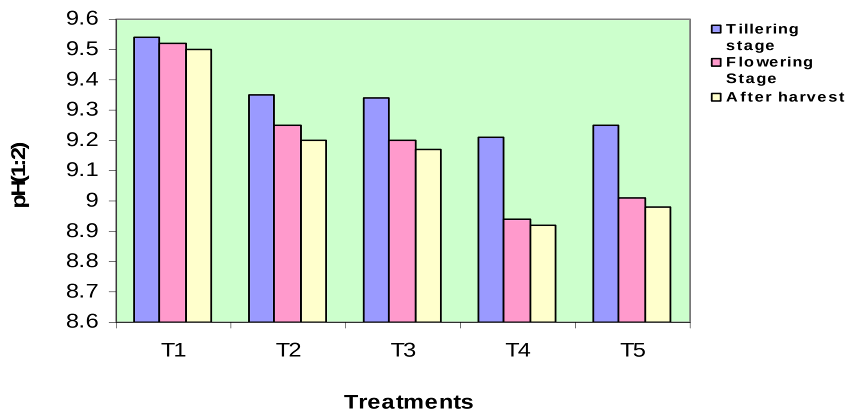

Fig. 5.20 : Effect of raw spentwash and gypsum application on pH of soil at different stages of paddy at VC farm Mandya

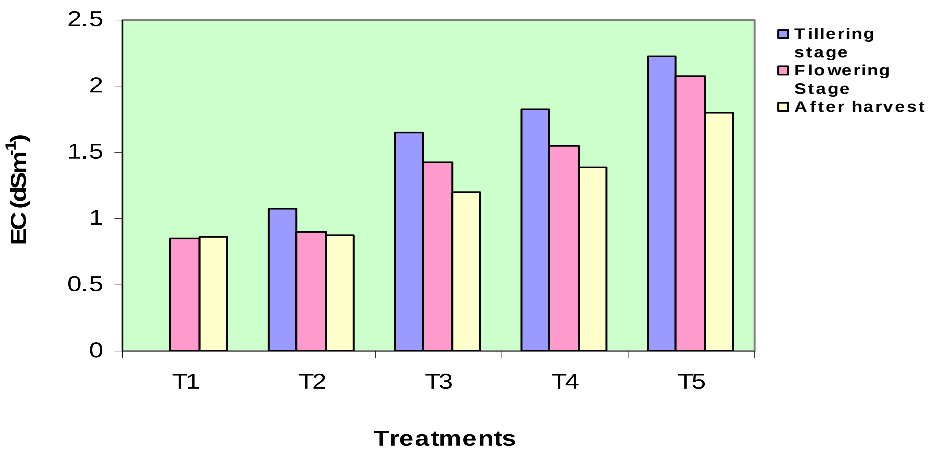

Fig. 5.21 : Effect of raw spentwash and gypsum application on EC of soil at different stages of paddy at VC farm Mandya

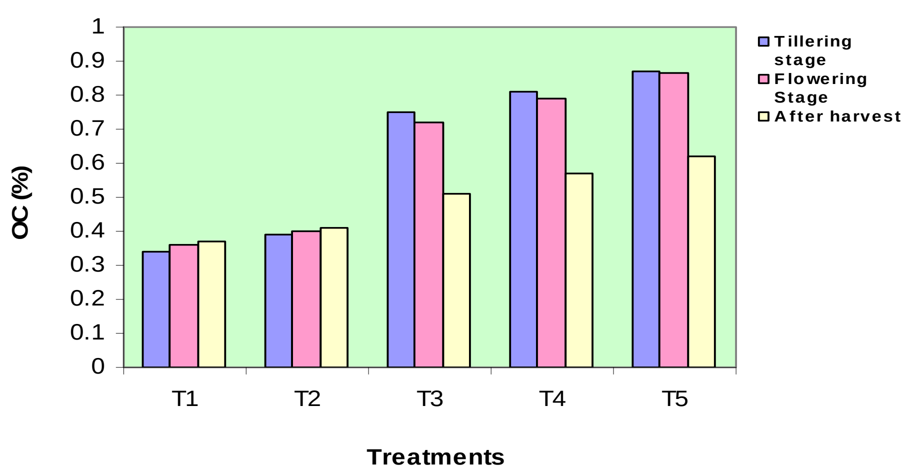

Fig. 5.22 : Effect of raw spentwash and gypsum application on OC of soil at different stages of paddy at VC farm Mandya

conformity with the findings of Clarson *et al.* (1984), Singh *et al* (1986), Patil *et al.*,(2000) and Baskar *et al*., (2003),Mahendra(2007).

5.2.2.1.4.3 Organic carbon

Organic carbon (OC) content of soil as influenced raw spentwash application is presented in Table 4.10 & Fig 5.22. Increased application of raw spent wash progressively increased the OC content of soil compared to gypsum and RDF plots.

Significantly higher OC was noticed with raw spentwash @ 7.5 lakh liters ha^{-1} followed by T_4 (RSW @ 5.0 lakh liters ha^{-1}) and T_3 (RSW @ 2.5 lakh liter ha^{-1}) respectively compared to T_2 receiving gypsum @ 100% GR and Rec NPK (no amendment). Similar trend was observed at flowering stage. Lowest OC (0.36per cent) was observed with rec NPK (no amendment). At harvest, significant accumulation of OC in soil was noticed with raw spentwash application. The increase in organic carbon content of soil can be attributed to the fact that effluent contained high organic load and also increase in root biomass. The results are line with Gurumurthy (1996) who reported increase in organic matter content of soil due to spentwash application.

5.2.2.1.4.4 Available nitrogen

Treatments receiving raw spentwash recorded significantly higher available N content of soil compared to T_2 receiving gypsum @ 100% GR and rec NPK (no amendment) (Table 4.11 & Fig.5.23). Highest available N was noticed with raw spentwash @ 7.5 lakh liters ha^{-1} followed by raw spentwash @ 5.0 lakh liters ha^{-1}, raw spent wash @ 2.5 lakh liters ha^{-1} and was significantly superior over T_2 (Gypsum @ 100% GR) and rec. NPK (no amendment). Similar trend was noticed at flowering and harvesting stage. Significantly higher available N content was accumulated in raw spentwash applied plots compared to gypsum amended and control plot. Suma (2006) reported that application of distillery spentwash upto 1000 m^3 ha^{-1} increased the available N content in all soils.

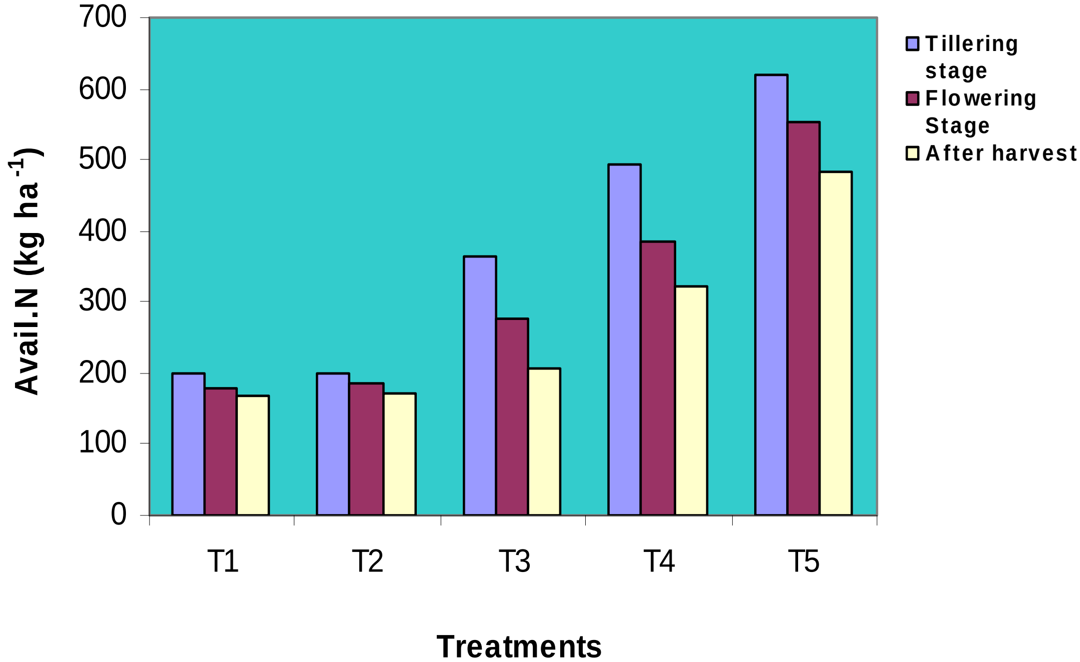

Fig. 5.23 : Effect of raw spentwash and gypsum application on Avail. nitrogen content of soil at different stages of paddy at VC farm Mandya

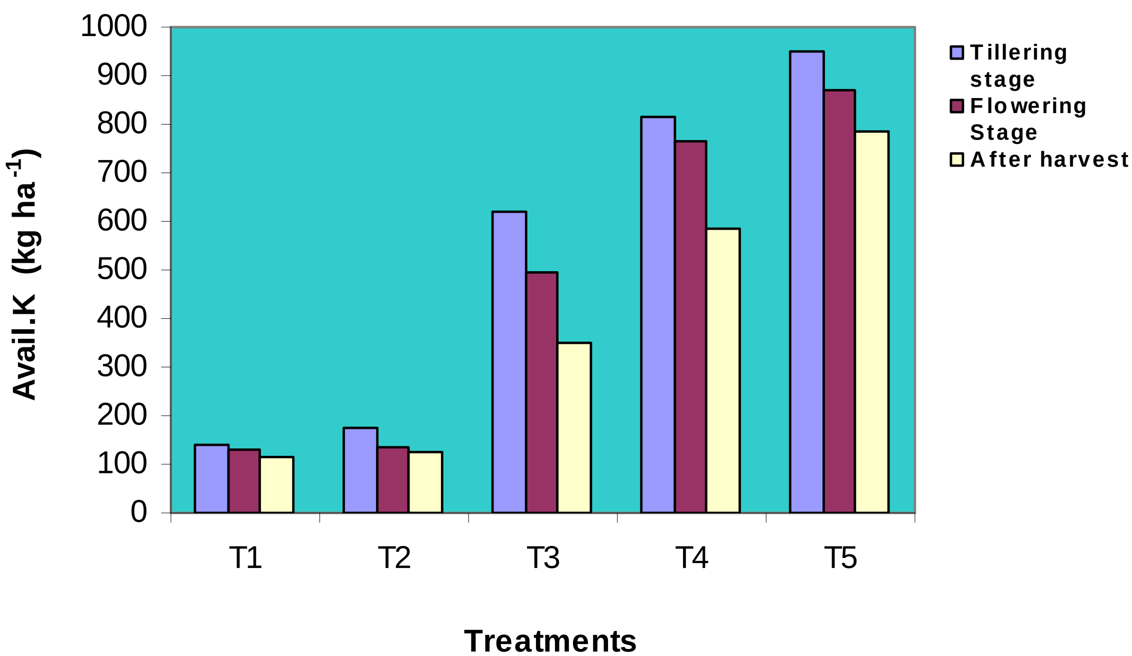

Fig. 5.24 : Effect of raw spentwash and gypsum application on Avail. Potassium content of soil at different stages of paddy at VC farm Mandya

5.2.2.1.4.5 Available phosphorus

Application of raw spentwash resulted in significant difference in available P content of soil (Table 4.11). Application of raw spentwash @ 7.5 lakh liters ha^{-1} recorded significantly higher available P followed by T_4 which received raw spentwash @ 5.0 lakh liters ha^{-1}. Lowest available P was noticed with Rec.NPK (without amendment) treatment. Increased levels of distillery spentwash application increased the P content in soil was (Goyal *et al.,* 2002 and Suma 2006).

5.2.2.1.4.6 Available potassium

Significantly highest available K in soil was recorded with application of raw spentwash at 7.5 lakh liters ha^{-1} followed by application raw spentwash at 2.5 and 5.0 lakh liters ha^{-1}, which were significantly superior over gypsum amended plots (Table 4.11 Fig.5.24). Available potassium content of soil increased significantly with increased levels of raw spentwash application in all soils. Highest available potassium was noticed with application of 7.5 lakh liters ha^{-1} distillery spentwash. Similar trend was noticed at flowering and harvesting stage. Significantly higher available K content was accumulated in raw spentwash applied plots compared to gypsum amended and control plot. Spentwash contains high amount of K (0.88 %) in ionic form, which upon application to soil readily builds up K (Nunes *et al.,* 1981, Somashekar *et al.,* 1984 and Patil *et al.,* 2000).

5.2.2.1.4.7 Exchangeable Calcium, Magnesium and Sodium content of soil

Application of raw spentwash significantly increased the exchangeable Ca and Mg content of soil and further increasing the quantity of raw spentwash application increased the exchangeable Calcium and magnesium content (Table 4.12 & Fig.5.25 & 5.26). Application of raw spentwash at the rate of 7.5 lakh liters ha^{-1} has recorded significantly higher exchangeable Ca and magnesium followed by raw spentwash @ 5.0 lakh liters ha^{-1} and was found significantly superior over all other treatments. Gypsum @ 100 % GR and raw spentwash @ 2.5 lakh liters ha^{-1} also recorded significantly higher exchangeable Ca and magnesium than treatment receiving rec.NPK (without amendment). Application of higher quantity of raw spentwash (7.5 lakh liters ha^{-1} and 5.0

lakh liters ha^{-1}), might have resulted in higher dissolution of free $CaCO_3$, thus increasing the calcium on exchange sites (due to its divalent nature, preferentially adsorb on clay surface). The acidic nature of raw spentwash (pH 4.1) might have solubilized native free lime which released Ca+Mg in free ionic forms which might have also contributed for increased Ca+Mg on exchange sites with the replacement of exchangeable sodium. Similar observations were also reported by Santiago Mahimaraja and Nanthi Bolan (2000), Taluk Medeiros (1989), Baskar *et al*., (2003) and Mahendra (2007) that application of raw spentwash increased the Ca and Mg contents of soil.

Exchangeable sodium in soil at different stages of crop growth was significantly influenced by application of raw spentwash. At tillering stage, treatment T_1 (rec.NPK without amendment) recorded significantly highest exchangeable Na and lowest was with raw spentwash @ 5.0 lakh liters ha^{-1}. While, effect of application of raw spentwash @ 2.5 lakh liters ha^{-1} was found on par with T_2 which received gypsum @ 100GR+Rec.NPK.Similar trend was also observed at flowering stage. The results are in accordance with the findings of Rachhpal Singh *et al.,* (1980) who reported that application of concentrated form of spentwash helped in greater exchange of sodium by calcium and subsequent leaching with good quality water replaced the sodium from the exchange sites. Similar observations were also reported by Mohammed Harron and Subash Chandra Bose (2004). Gypsum when applied to soil undergoes solublization producing calcium and sulphate ions. The calcium ions in solution replaces the sodium on the exchange complex which is then leached out as sulphate salt. Similar results were also reported by Somani, (1990) and Srinivasa, (1995) that application of gypsum decreased the exchangeable sodium content of soil.

5.2.2.1.4.8 ESP

Significant reduction in exchangeable sodium percentage of soil was recorded in T_4 which received raw spentwash @ 5.0 lakh liters ha^{-1} followed by T_5 which received raw spentwash @ 7.5 lakh liters ha^{-1} and was significantly superior over T_1 (Rec.NPK without amendment) which recorded significantly highest exchangeable sodium percentage (Table 4.12 & Fig.5.27). While, Gypsum @ 100 %GR+Rec.NPK recorded

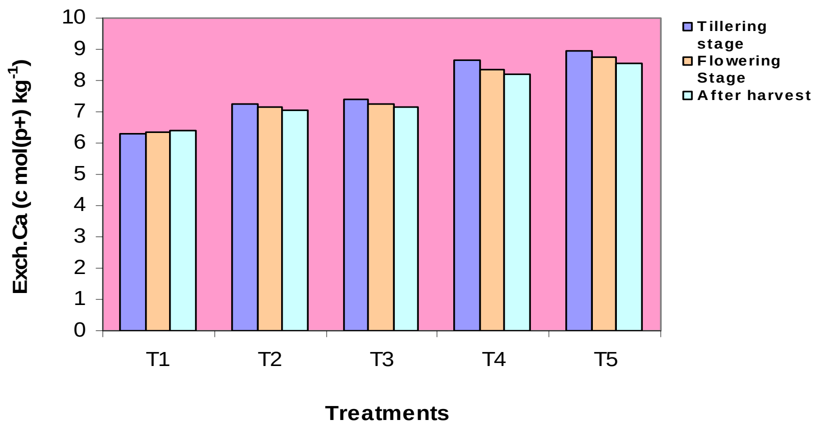

Fig. 5.25 : Effect of raw spentwash and gypsum application on Exch. Ca content of soil at different stages of paddy at VC farm Mandya

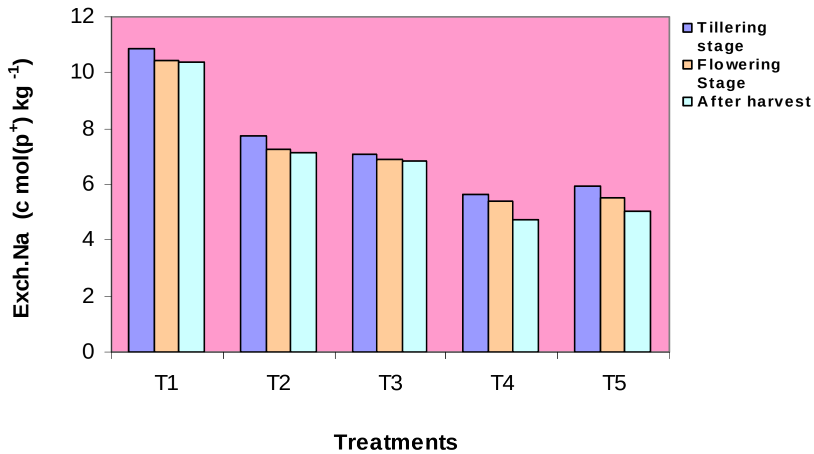

Fig. 5.26 : Effect of raw spentwash and gypsum application on Exch. Na content of soil at different stages of paddy at VC farm Mandya

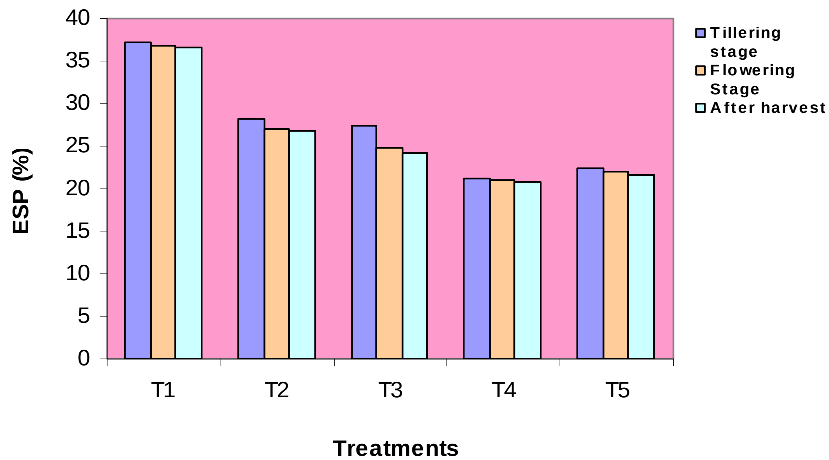

Fig. 5.27 : Effect of raw spentwash and gypsum application on ESP of soil at different stages of paddy at VC farm Mandya

exchangeable sodium percentage which was on par with T_2 which received application of raw spentwash @ 2.5 lakh liters $ha^{-1.}$ The reduction in ESP was attributed to replacement of exchangeable sodium ions by calcium of gypsum and raw spentwash and calcium released by the dissolution of native calcium carbonate present in soil brought about by raw spentwash due to its acidic nature. Similar results were also reported by Valliappan (1998) and Thiyagarajan (2001). Effect of gypsum in reducing the ESP due to removal of soluble sodium sulphate salt formed due to adsorption of calcium present in gypsum was also reported by Verma *et al*. (1985) and Srinivasa (1995).

5.2.2.1.4.9 Micronutrients

DTPA extractable micronutrients content of soil as influenced by application of raw spentwash at all growth stages is given in (Table 4.14). Significantly highest amount of micronutrients like Fe, Mn, Zn, Cu were recorded in T_5 which received 7.5 lakh liters ha^{-1} of spentwash followed by T_4 &T_3 which received 5.0 lakh liters ha^{-1} and 2.5 lakh liters ha^{-1} of spentwash compared to gypsum and no amendments plot at all the stages of paddy crop. When compared to initial value a definite build up of these metallic cations was recorded in the soil as a consequence of use of raw spentwash might be attributed to an increase in organic carbon content of the soil resulting in higher adsorption of the metallic cations.(Totawat 1991, Marsh and Siceama 1997, Garg and Totawat, 2005 and Patel *et al.,* 2004) also reported that among soil properties, organic carbon showed significant positive correlation with most of the trace metals was the most influential parameter on availability of elements. The build up of all these metallic cations significantly increased with an increased level of spentwash. The results of the present investigation are also in agreement with the findings of Zalwadia *et al* (1997), Kayalivzhi *et al.* (2001), Valliappan *et al*. (2001)

5.2.2.1.5 Piezometer studies

5.2.2.1.5.1 Effect of different quantities of spentwash application on chemical composition of leachate

Increasing the quantities of raw spentwash application significantly increased the pH, EC, HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+} and Na^+, in leachate samples Table 4.15. Similar observations were made by Devarajan and Oblisami (1995) and Malathi (2002).

At 30days after application, pH and EC of the leachate was increased which might be due to leaching of salts. Among the anions HCO_3^{-1} concentration was more followed by Cl^- and SO_4^{2-}. Among cations quantity of Na^+ was leached more compared to Ca^{2+} and Mg^{2+} as it is monovalent and retention on exchangeable site is less compared to Ca^{2+} and Mg^{2+} which are divalent in nature and get strongly adsorbed on clay surface. Similar results of increased salt content in ground water near lagoon sites around most of the distilleries was noticed by Joshi *et al*. (1994). Husain *et al*. (2003), Anilkumar *et al*. (2003) and Malathi (2002) Suma (2006) noticed the leaching of anions and cations from soil profile with application of spentwash.

5.3 Ferti-irrigation studies in Paddy

5.3.1 Green House Experiment II: Effect of ferti-irrigation of spentwash on growth and yield components of paddy

5.3.1.1 Growth parameters

The plant height, number of tillers, number of panicles number of seeds per panicle were greater with application of spentwash (Table 4.16).Growth parameters at harvest of paddy crop were highest with distillery spentwash ferti-irrigation at 150 per cent RDN. All the treatments, which received the spentwash responded well compared to treatments receiving only chemical fertilizers. This might be due to the presence of all essential nutrients, which might have stimulated the growth of paddy. Singh and Raj Bahadur (1997) and Ramanna *et al*., (2001), Suma (2006) recorded similar observations on improved growth and yield attributing characters due to spentwash application to crops.

5.3.1.2 Effect of ferti-irrigation of spent wash on grain and straw yield

The grain and straw yield reflected the trend observed in various growth and yield parameters as influenced by ferti-irrigation of distillery spentwash on paddy (Table 4.16 & Fig.5.28). Grain yield increased significantly due to ferti-irrigation of spentwash. Highest yield was noticed with application of distillery spentwash @ 150% RDN (in 3 irrigations) recorded highest yield followed by 150% N through urea in (3irrigtaion) and RDF (NPK) + FYM. Similar trend was noticed as that of grain yield was observed with respect to fodder yield. Significantly highest straw yield was recorded in T_{14} treatment which received 150% RDN through distillery spentwash in 3 irrigations followed by T_{15} and T_8, T_{13}, $T_{1.}$ Application of RDF+FYM recorded which was on par with150% RDN through distillery spentwash in 6 irrigation, 150% RDN through urea (20% in each irrigation) & 150%, 100% RDN through distillery spentwash (33% & 50% in each irrigation). Significantly lowest yield was recorded in 100% RDN through urea (20% in each irrigation) and was on par with 150% RDN through distillery spentwash (6irrigation) followed 100% RDN (33 & 50% in each irrigation). This might be due to lesser availability of nutrients and consequently poor growth and yield parameters.

The higher grain yield and straw in these treatments may be attributed to improvement in various growth and yield parameters *viz.*, plant height, number of tillers, number of panicles, and number of seeds per panicle due to application of distillery spentwash. Similar observation was made by Dinesh Kumar (1993) who asserted that the cane yield responded upto 250 kg N ha^{-1} as a consequence of increase in various growth and yield parameters. Suma (2006) reported that ferti-irrigation of distillery spentwash at 150 per cent RDN recorded highest cane and sugar yield.

5.3.1.3 Effect of ferti-irrigation of spentwash on nutrient composition of paddy

5.3.1.3.1 Nitrogen

Application of 150% RDN through distillery spentwash (33% in each irrigation) recorded significantly higher nitrogen in paddy crop compared to other treatments (Table 4.17 & Fig.5.29). This may be due to slow release of N from spentwash which might have maintained higher N potential in soil and consequently satisfied N requirement of

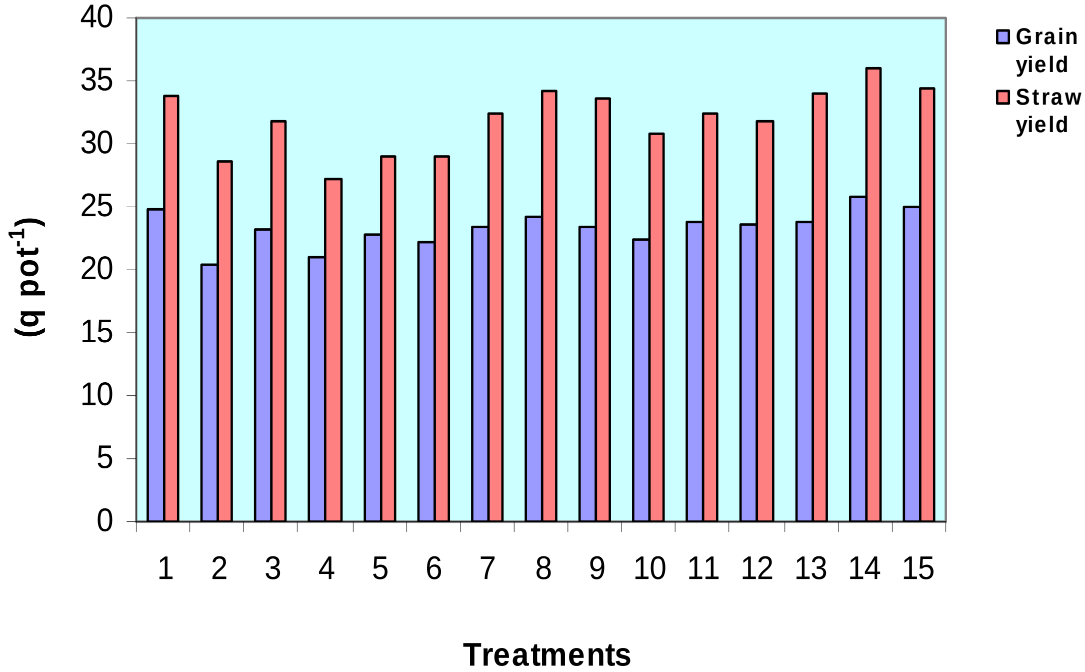

Fig. 5.28 : Effect of Ferti-irrigation of spentwash on grain and straw yield of paddy

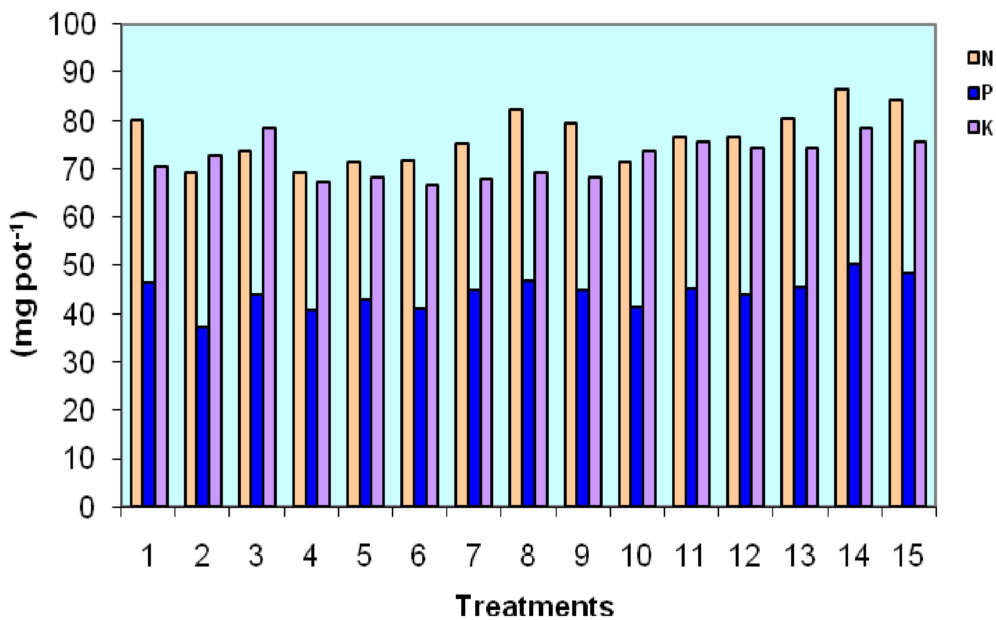

Fig. 5.29 : Effect of Ferti-irrigation of spentwash on nutrient uptake by paddy

crop. Significantly lowest N uptake was recorded in treatment which received 100% RDN through urea (20% in each irrigation) followed by 100% RDN through distillery spentwash in 6 irrigations.

5.3.1.3.2 Phosphorus

Significantly highest P uptake was recorded in T_{14}, T_{15} followed by T_1 which received 150% RDN through distillery spentwash (33% and 50% in each irrigation) & RDF+FYM respectively (Table 4.17 & Fig.5.29). Apart, from availability, improved N management and higher N accumulation in plant might have enhanced the P concentration and thus the growth and uptake.

5.3.1.3.3 Potassium

Ferti-irrigation with 150% RDN through distillery spentwash (33% in each irrigation) recorded significantly higher value and was on par with, (T_2 and T_{15}). 100% RDN through distillery spentwash recorded significantly higher values compared to 150% RDN through urea (33% in each irrigation), 100% RDN through urea and RDF+FYM and 150% RDN through urea in (50% in each irrigation) (Table 4.17 & Fig.5.29). This is obvious, as very high quantity of K is added to soil with ferti-irrigation of distillery spentwash. (Shinde *et al.,* 1993 and Zalawadia *et al.,* 1997) reported that Sugarcane being heavy feeder of K accumulated K at higher concentration with increased availability of K in soil.

5.3.1.3.4 Sulfur

Sulfur uptake was observed with application of RDF + FYM and RDF treatments, which was on par with distillery spentwash ferti-irrigation at 150 per cent RDN (Table 4.17). The increased concentration of S in these treatments is attributed to increased uptake and accumulation N and P and also due to the presence of appreciable quantity of S in spentwash which might have enhanced the S uptake. Srivastava and Singh (1993) reported that N and P have positive effect on S uptake and accumulation, increased N and P concentration in tissue and thus enhances S accumulation.

5.3.1.4 Effect of ferti-irrigation of spentwash on chemical properties of soil

5.3.1.4.1 Soil reaction

Soil reaction differed significantly due to distillery spentwash application compared to chemical fertilizer applied plots (Table 4.18). Significant increase in pH was observed in treatments, which received distillery spentwash. The results are in accordance with Machaado-de-Armas *et al.,* (1994), Singh and Raj Bahadur (1998) and Pathak *et al*. (1999), who observed marginal, increase in pH of soil with application of distillery spentwash.

5.3.1.4.2 Electrical Conductivity

Salt content of soil differed significantly due to ferti-irrigation of spentwash. Application of distillery spentwash marginally increased the EC after the harvest of crop when compared to RDF treatments and also initial EC value of soil (Table 4.18). This is attributed to the presence of high salts in spentwash, which upon application to soil might enhance the EC. Salt content after the harvest of the crop was below the thresh hold level (0.8 dS m^{-1}). Scandaliaris *et al.* (1987), Zalawadia and Raman (1994), Joshi *et al*. (1996) and Hati *et al.* (2005) have reported increased electrical conductivity of soil with usage of spentwash.

5.3.1.4.3 Organic Carbon

Ferti-irrigation of distillery spentwash significantly increased the OC content of soil (Table 4.18). After harvest of crop, highest Organic carbon was noticed in treatments involving distillery spentwash applied and RDF + FYM. However, ferti-irrigation of distillery spentwash resulted in higher organic carbon compared to RDF treatments and was on par with RDF + FYM. Spentwash contains very high organic load which upon application to soil is known to enhance the organic carbon content. However, with advance of time, it will under go rapid decomposition and ultimately results in marginal increase of Organic carbon, due to the formation of little quantity of humic and fulvic acid (Ramadurai and Gerard, 1994 and Arafat Sayed and Yassen Abd Elazim, 2002). The present findings are in line with Zalawadia and Raman (1994), Canellas *et al.* (2003) and Hati *et al.* (2005), Suma (2006).

5.3.1.4.4 Available nitrogen

Available N in soil differed significantly due to ferti-irrigation of distillery spentwash (Table 4.19). Application of distillery spentwash significantly increased the available N in soil compared to RDF treatments. This indicates that with increased distillery spentwash application, nitrogen content in soil increased, which upon triggers the microbial activity and may result in mineralization of organic nitrogen compounds and there by enhances availability of N.

Ferti-irrigation of distillery spentwash recorded highest available N content of soil and was found on par with RDF + FYM. This reflects the mineralization of N from spentwash and available to plants at advanced stages of crop growth. This will have both positive and negative effects. In the treatments receiving only distillery spentwash, initial N requirement of the crop could not be fully met due to its slow releasing pattern. On other hand, slow release of N from spentwash decreases the N loss from soil and maintains higher N potential through out the plant growth period. Thus the application of urea and distillery spentwash at 150 per cent RDN was found better in terms N management and consequently better N uptake by crops. Suma (2006) also obtained similar results in sugar cane.

Similar observations were made by Kulkarni *et al.* (1987) who opined that spentwash contains N chiefly in organic colloidal form and behaved as slow releasing fertilizer upon application to soil. Many researchers reported improved availability of N in soil with application of distillery spentwash (Zalawadia and Raman, 1994, Singh and Raj Bahadur, 1998, Joshi *et al*. 1996 and Sukanya and Meli, 2003)

5.3.1.4.5 Available phosphorus

Available P content of soil did not differ significantly due to application of distillery spentwash (Table 4.19). However, marginal increase in available P was noticed in treatments receiving distillery spentwash compared to RDF. This may be due to organic nature of P in spentwash, which may take some time to get decomposed into available form. Kulkarni *et al.* (1987) reported that two thirds of the phosphorus in spentwash is organic in nature. Some researchers recorded improved available P in soil with application of spentwash (Shindhe *et al*., 1993, Zalawadia and Raman, 1994 and Zalawadia *et al*., 1997, Suma 2006)). On the contrary, Machaado-de-Armas *et al.* (1994) reported decreased P availability in soils with spentwash application.

5.3.1.4.6 Available potassium

Ferti-irrigation of distillery spentwash at 150 per cent RDN and at 100% RDN significantly increased available K content of soil and these treatments were superior over RDF (Table 4.19).

Higher amount of potassium was accumulated in soil in treatments receiving distillery spentwash. This may be due to the fact that, spentwash contains substantial amount of K (1.15 %) which is mostly in ionic form (Kulkarni *et al.*, 1987) and becomes immediately available to plants. Also, distillery spentwash application based on the N requirement of paddy crop, added high amount of K, which is more than the crop's requirement and thus the excess K might have accumulated in soil exchange complex. This is in confirmity with the findings of Joshi *et al*. (1996), Paula *et al.* (1999) and Sukanya and Meli (2003), Suma (2006).

5.3.1.4.7 Exchangeable calcium, magnesium and available sulfur

Exchangeable Ca and Mg differed significantly due to spentwash application after the harvest of crop (Table 4.19 & Table 4.20). Ferti-irrigation of distillery spentwash at 150 per cent RDN recorded higher Ca and Mg contents of soil than at RDN level. Distillery spentwash ferti-irrigation at 150 per cent RDN marginally increased the Ca and Mg contents. This is attributed to the presence of appreciable quantities of Ca and Mg in spentwash.Similar results were noticed by Patil *et al.,* 1987, Bhat, 1994, Zalwadia *et al.,* 1997 and Sukanya and Meli, 2004 that spentwash application to soil increased the Ca and Mg content and also supported by Taluk and Medeiros, 1989, Pawar *et al.,* 1992, Paula *et al.*, 1999 and Madhusudhana, 2006.

Ferti-irrigation of distillery spentwash significantly increased the available sulfur content of soil compared to other treatments involving fertilizers. Marginal increase in available S was noticed in distillery spentwash ferti-irrigation at 150 per cent RDN and RDN treatments. Zalwadia *et al.* (1997) indicated increased available S in soil with application of spent wash over control. Suma (2006) and Madhusudhana (2006) also reported that application of spentwash increased the available S in soil.

5.3.1.4.8 Exchangeable sodium

Exchangeable Na content of soil differed significantly due to ferti-irrigation of spentwash (Table 4.20). Ferti-irrigation of distillery spentwash at 150 per cent RDN accumulated significantly higher sodium compared to RDF and RDF+FYM. The present result is in accordance with Anil Kumar (1995) Murugaragavan (2002) and Suma (2006). They noticed marginal increase in exchangeable Na and were below the threshold level, suggesting that application of spentwash will not cause sodicity problem in soil.

5.3.2 Field experiment –II Effect of ferti-irrigation of spentwash on growth and yield of paddy in sodic soil

5.3.2.1 Growth and yield parameters

Ferti-irrigation of spentwash significantly influenced the growth and yield parameters of paddy after reclamation of sodic soil (Table 4.21). Significant increase in growth and yield parameters was noticed with the application raw spentwash than gypsum application.

Treatment RSW @ 100% GR+100% RDN through SW (3splits), followed by T_8 (32.67g), T_{10} (32.32g) were on par with each other. Application of gypsum @100% GR + Recommended NPK was on par in T_3 (RSW @ 50% GR +50% RDN through SW (3splits) and treatments which received 100% RDN and 150% RDN through spentwash respectively. Lowest thousand grain weight (22.64 g) was recorded in treatment receiving gypsum @ 50% GR + recommended NPK. The increase in growth and yield parameters might be due to proper utilization of major and micronutrients by the crop. Similar results were obtained by Pujar and Manjunath, (1996) Doddagoudar and Alagawadi, (2001) and Ananthkumar, (2002).

5.3.2.2 Effect of ferti-irrigation of spent wash on grain and straw yield

The grain and straw yield reflected the trend observed in various growth and yield parameters as influenced by ferti-irrigation of distillery spentwash on paddy (Table 4.21& Fig 5.30 & Plate11). Grain yield increased significantly due to ferti-irrigation of spentwash. Highest grain yield was recorded in RSW @ 100% GR+100% RDN through SW (3splits) and lowest grain yield was recorded in T_1 which received gypsum @50% GR + Recommended NPK. Straw yield of paddy also followed the similar trend as that of grain yield. Significantly highest straw yield was recorded in T_{10} (RSW @ 100% GR+100% RDN through SW (4splits) followed by T_9. Whereas application of RSW @ 50% GR +100% RDN through SW (3splits) recorded higher yield and was found significant superior over T_2 receiving gypsum @ 100% GR + Recommended NPK.

The higher grain and straw yield in these treatments is attributed to improvement in various growth and yield parameters *viz.,* plant height, number of tillers, number of seeds per panicle and thousand grain weight due to application of distillery spentwash. Also application of raw spentwash one month before transplanting might have improved the physical conditions of the soil by replacing exchangeable sodium with calcium and also over all nutrients status of soil. Also application of treated spentwash through irrigation has provided the nutrient requirement of crop at later stages. Improved physical and chemical properties of soil helped in better uptake of water and nutrients thus resulting in higher yield.

5.3.2.3 Effect of ferti-irrigation of spentwash on nutrient composition of paddy

5.3.2.3.1 Nitrogen, phosphorus and potassium uptake

Total uptake of nitrogen phosphorus and potassium was significantly influenced by ferti-irrigation of spentwash (Table 4.22 & Fig 5.31). Highest uptake was recorded in treatment receiving RSW @ 100% GR+100% RDN through SW in 3splits. However, treatment receiving raw spentwash @ 100% RDN recorded significantly lower uptake

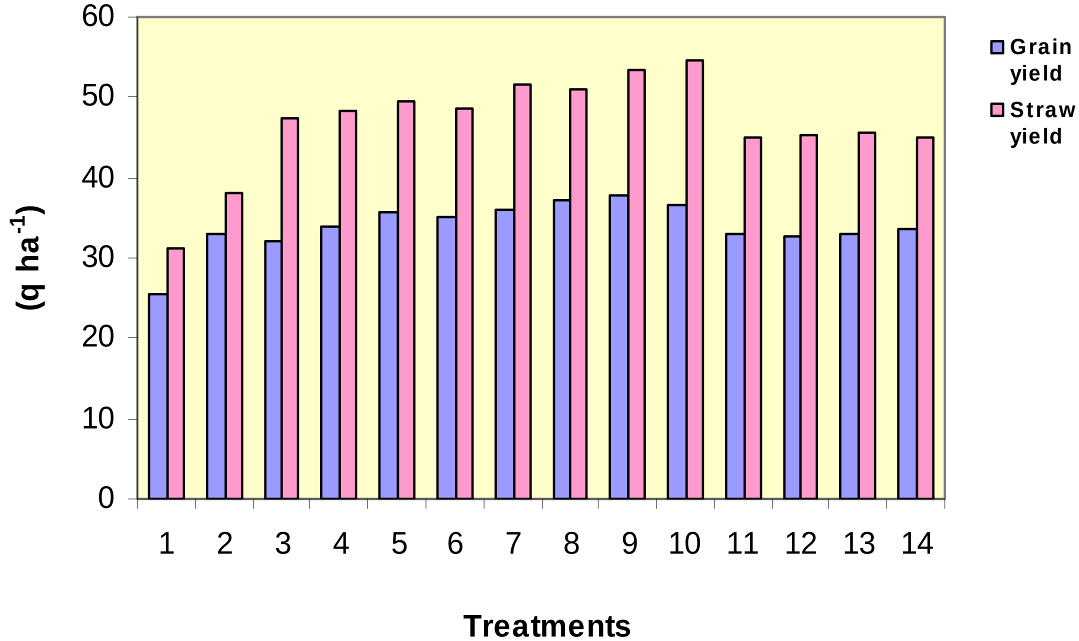

Fig. 5.30 : Effect of Ferti-irrigation of spentwash on grain and straw yield of paddy at VC farm ,Mandya

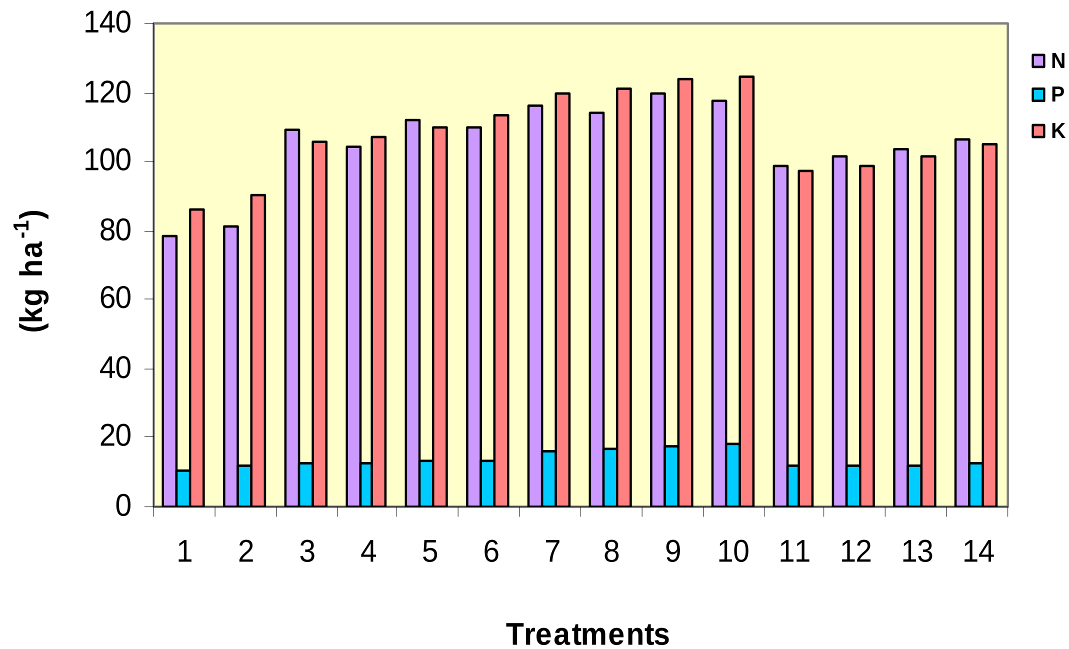

Fig. 5.31 : Effect of Ferti-irrigation of spentwash on nitrogen, phosphorus and potassium uptake by paddy at VC farm, Mandya.

Plate 11 : Paddy crop with spentwash at 50 and 100% GR (3 & 4 splits)

compared to RSW @ 50% GR + 50% RDN through SW (3splits) but was significantly superior over T_2 which received gypsum @100%GR+Rec.NPK. Highest uptake of these major nutrients might be due to beneficial effect of raw spentwash in reclaiming the sodic soil and also additional nutrients (especially nitrogen and potassium provided through treated spentwash through irrigation.

5.3.2.3.2 Calcium, magnesium and sulfur

Application of spentwash significantly influenced the calcium, magnesium and sulfur uptake by paddy and highest values were recorded in treatment receiving RSW @ 100% GR+100% RDN through SW in 3 splits and significantly lowest uptake was recorded in T_1 which received gypsum @50% GR + rec. NPK (Table 4.22& Fig 5.32). Highest uptake of all these nutrients may be due to high amount of calcium, magnesium and sulfur present in spentwash.

5.3.2.4 Effect of ferti-irrigation of spentwash on chemical properties of soil

5.3.2.4.1 Soil pH

Soil pH differed significantly due to basal application of raw spentwash and due to ferti-irrigation of spentwash during crop growth (Table 4.23 &Fig 5.33). Reduction in soil pH was lowest in T_9 which received RSW @ 100% GR+100% RDN through SW (3splits) and highest (8.79) was in T_1 (Gypsum@50% GR+ rec.NPK). This might be due to good amount of calcium present in raw spentwash compared to gypsum which was not sufficient for replacing sodium on the exchange complex.

5.3.2.4.2 Electrical Conductivity

Effect of ferti-irrigation of spentwash significantly increased the electrical conductivity (EC) of soil (Table 4.23 & 5.33). Increase in soil EC was more in spentwash amended plots compared to gypsum applied plots. Significantly highest EC (1.20 dS m^{-1}) was recorded in T_{10} (RSW @ 100% GR+100% RDN through SW (3splits)) compared to treatment receiving gypsum @ 50% GR+Rec.NPK & gypsum @ 100% GR. Increase in soil EC after effluent application was also reported by Jadhav and Savant (1975), Pathak *et al*.,(1999), Scandalaris *et al* 1987, Zalawadia and Raman (1994) and Joshi *et al* (1996),

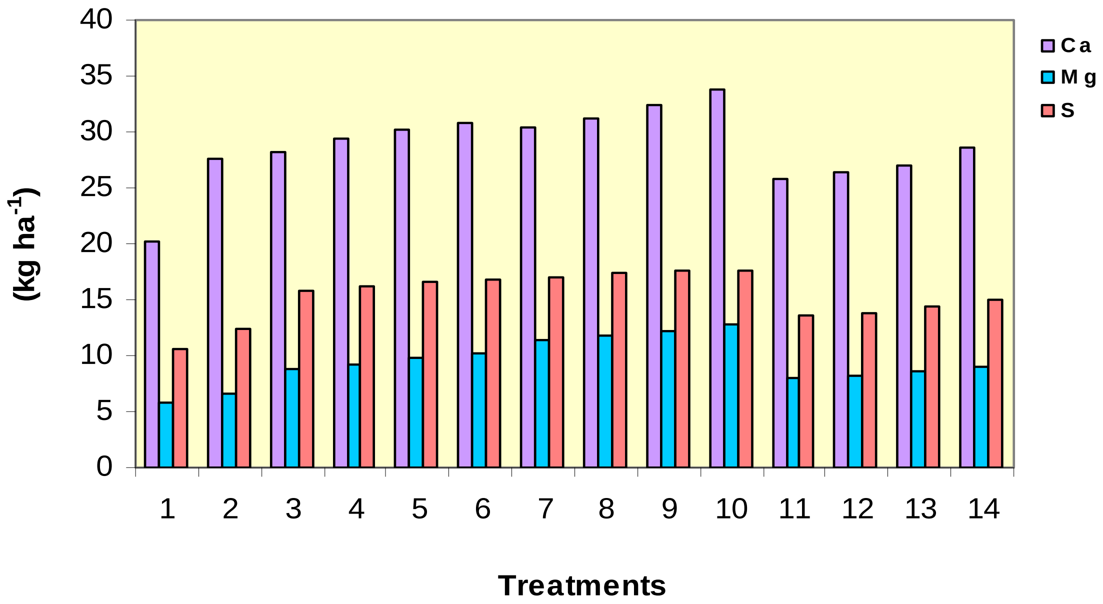

Fig. 5.32 : Effect of Ferti-irrigation of spentwash on calcium, magnesium and sulphur uptake by paddy at VC farm ,Mandya

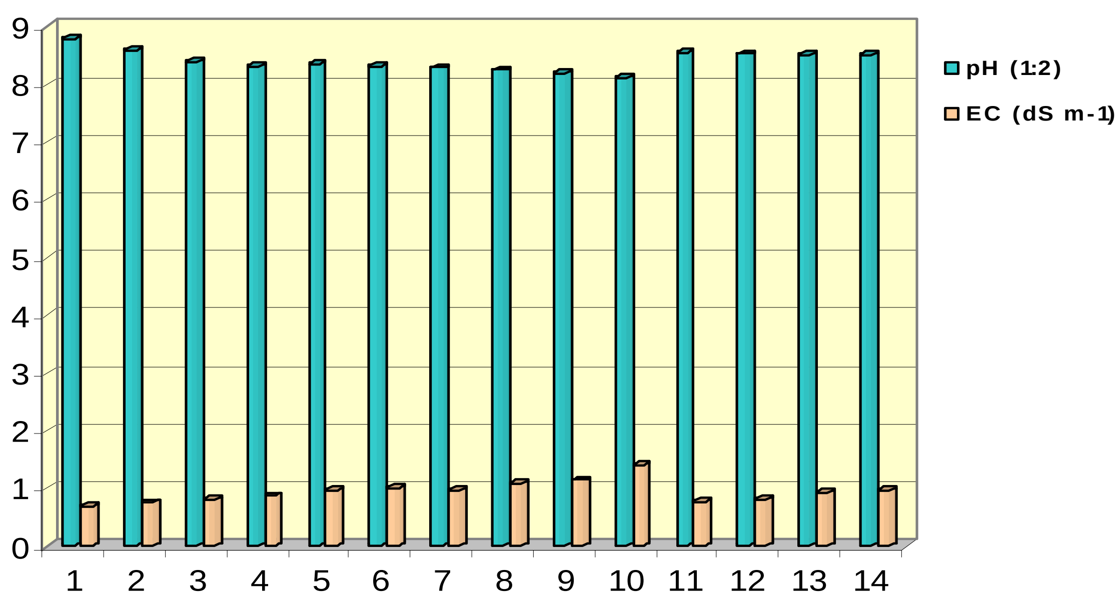

Fig. 5.33 : Effect of ferti-irrigation of spentwash on pH and EC of soil after harvest of paddy at VC farm Mandya

The results are in accordance with the findings of Baskar *et al.* (2003) who reported increased EC in soil due to application of distillery spentwash.

5.3.2.4.3 Organic carbon

Significant accumulation of organic carbon in soil was noticed in RSW @ 100% GR+100% RDN through SW (4splits) which was significantly superior over T_1 and T_2 which received gypsum @50% GR and 100% GR respectively (Table 4.23). Increased application of raw spent wash progressively increased the organic carbon content of soil compared to gypsum applied plots. The increase in organic carbon content of soil can be attributed to the fact that effluent contained high organic load which triggered the microbial activity and contributed for increase in organic carbon content. The results are line with Gurumurthy (1996): Mattiazzo and Ada Gloria (1985), Singh and Rajabahadur (1998). Pathak *et al.* (1999) also reported that significantly high organic carbon was accumulated in the soil irrigated with effluent.

5.3.2.4.4 Available nitrogen, phosphorus and potassium content of soil

Available N content of soil at different crop growth stages of paddy was significantly influenced by ferti-irrigation of spentwash (Table 4.24 & Fig 5.34 & 5.35). At tillering stage, ferti-irrigation of spent wash significantly influenced the available nitrogen content of soil. Higher amount of nitrogen was recorded in spentwash amended plots compared to gypsum applied plots. Significantly highest amount of these available nutrients was recorded in T_{10} RSW @ 100% GR+100% RDN through SW (4splits) and was significantly superior over RSW @ 50% GR and 100 and 150% RDN through spentwash. Significantly lowest values were recorded in treatments which received gypsum @50% GR (T_1) and 100% GR (T_2). This trend of results in spentwash applied plots might be due to higher amount of nutrients especially nitrogen and potassium added through very high levels of spentwash.

5.3.2.4.5 Exchangeable Calcium, magnesium and available Sulfur content of soil

Exchangeable Ca and Mg differed significantly due to spentwash application after the harvest of crop (Table 4.25 & Fig 5.36). Significantly highest amount of these

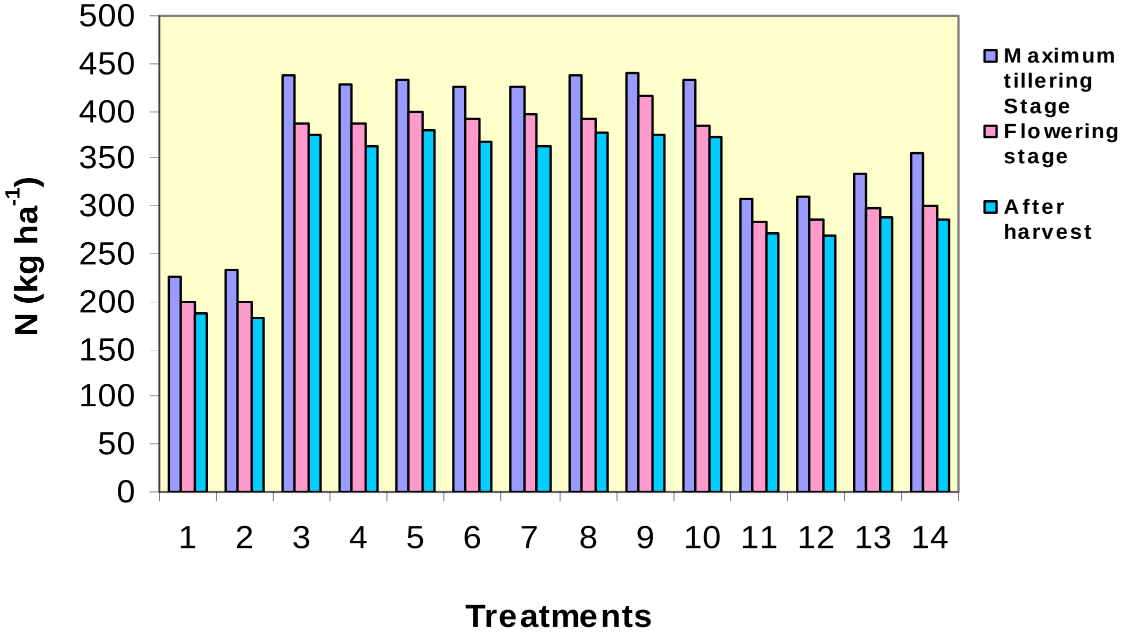

Fig. 5.34 : Effect of ferti-irrigation of spentwash on avail. nitrogen content of soil at different growth stages of paddy at VC farm Mandya

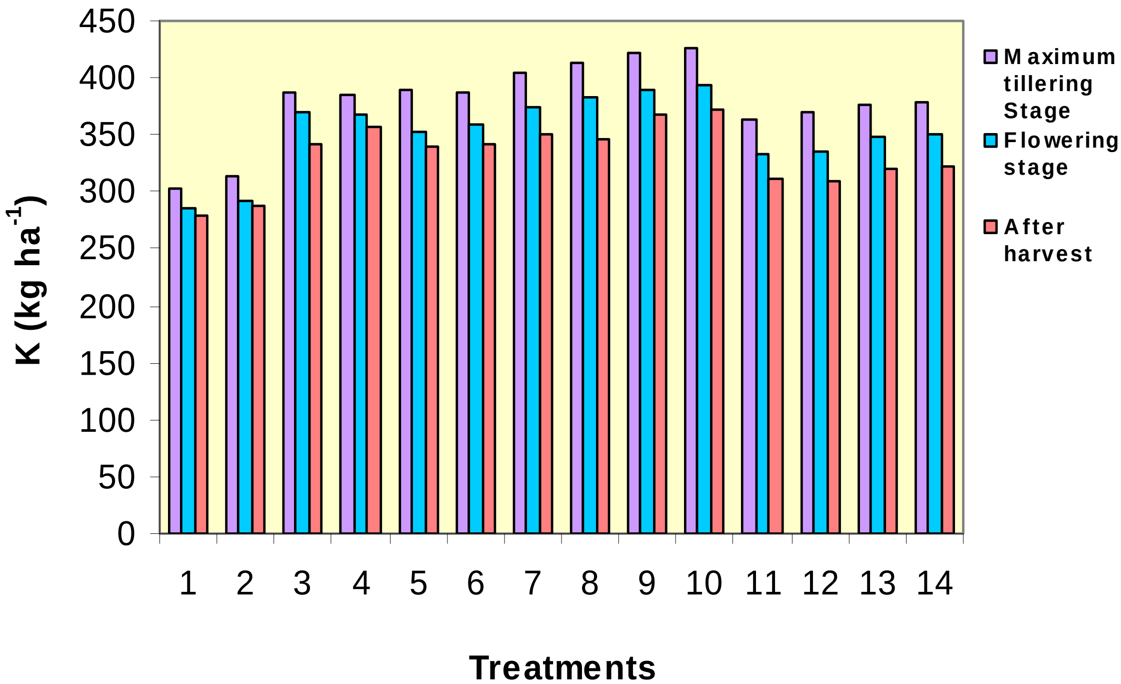

Fig. 5.35 : Effect of ferti-irrigation of spentwash on avail. potassium content of soil at different growth stages of paddy at VC farm Mandya

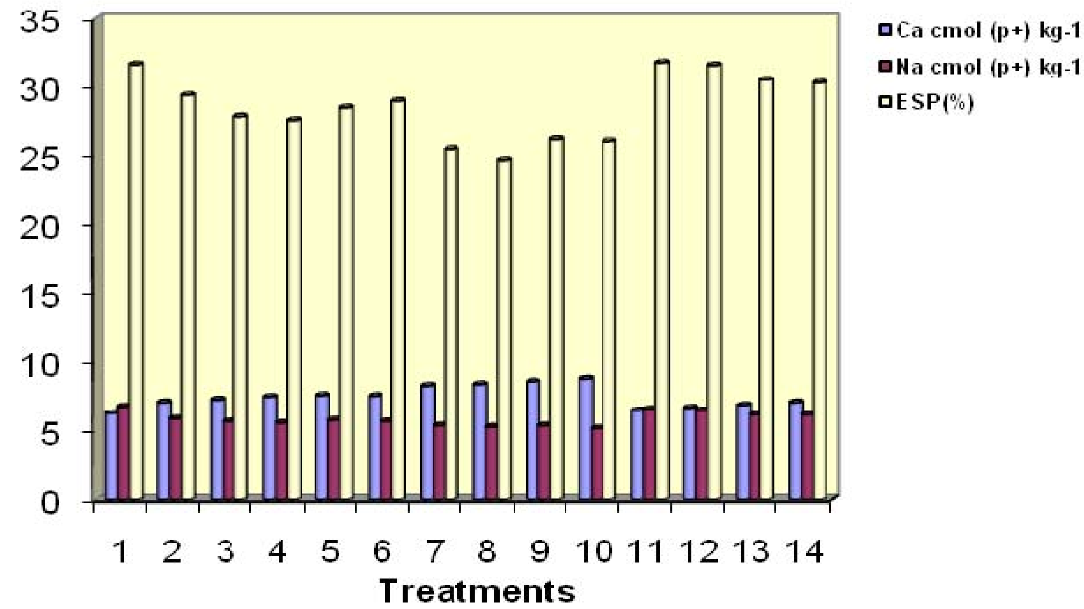

Fig. 5.36 : Effect of ferti-irrigation of spentwash on calcium, sodium & ESP of soil after harvest of paddy at VC farm Mandya

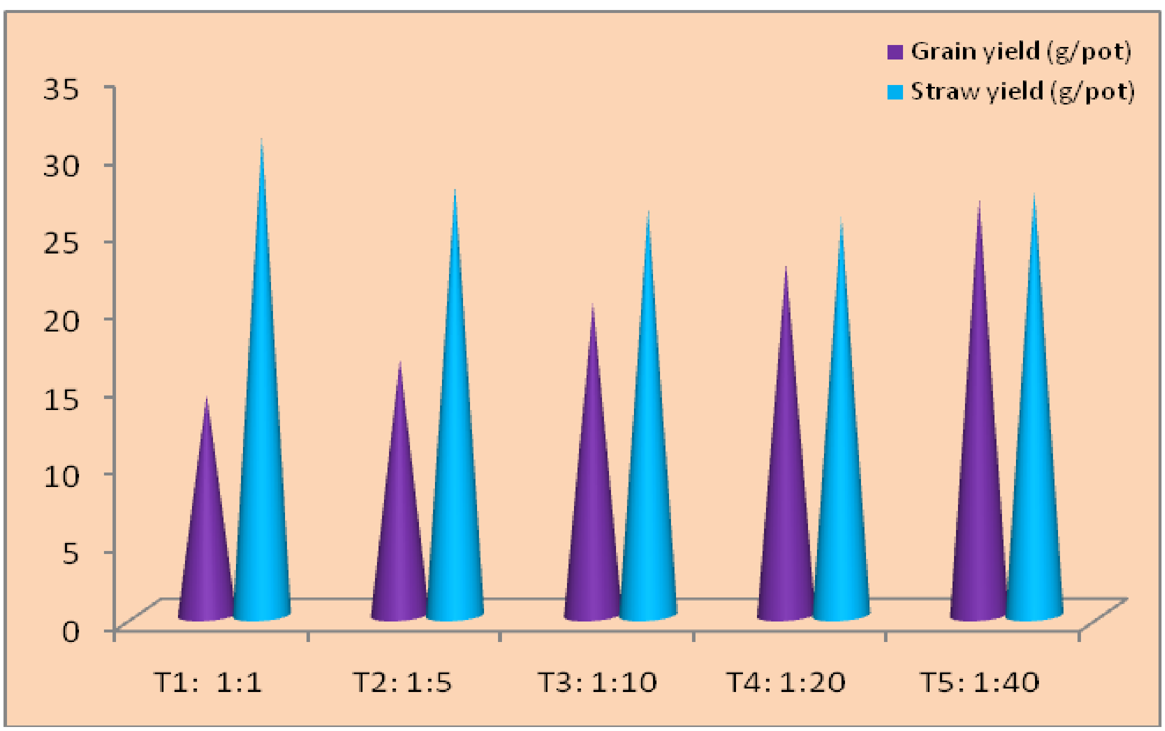

Fig. 5.37 : Effect of different dilutions spent wash application on grain & straw yield of paddy

available nutrients was recorded in T_{10} receiving RSW @ 100% GR+100% RDN through SW (4splits) and was significantly superior over RSW @ 50% GR and 100 and 150% RDN through spentwash. This is attributed to the presence of appreciable quantities of Ca and Mg in spentwash which upon application to soil increased the Ca and Mg content and the result was supported by the findings of Patil *et al.* 1987, Taluk and Medeiros, 1989, Pawar *et al.* 1992, Bhat, 1994, Zalwadia *et al.* 1997, Paula *et al.* 1999, and Sukanya and Meli, 2004 and Madhusudhana, 2006.

Ferti-irrigation of distillery spentwash significantly increased the S content of soil compared to other RDF treatments. Marginal increase in available S content of soil was noticed in distillery spentwash ferti-irrigation at 150 per cent RDN and RDN treatments. Zalwadia *et al.* (1997) indicated increased available S in soil with application of spent wash over control. Suma (2006) and Madhusudhana (2006) also reported that application of spentwash increased the available S in soil.

5.3.2.4.6 Exchangeable Sodium

Exchangeable Na content of soil differed significantly due to ferti-irrigation of spentwash (Table.4.25 & Fig.5.36). Application of RSW @ 100% GR+100% RDN through SW (4 splits) recorded significantly lower exchangeable sodium compared to other treatments. This may be due to the fairly good amount of calcium present in spentwash which might have replaced the sodium on the exchange complex and also due to leaching because it was held very loosely on the exchange complex compared to calcium and magnesium ions.

5.4 Green House experiment III: Effect of spentwash application of different dilutions on growth and yield of paddy

5.4.1 Growth and Yield parameters

Growth and yield parameters viz., Plant height and number of tillers, number of panicles, and number of filled grains per panicle were increased significantly due to application of spentwash in different dilutions (Table 4.26). Plant height, number of tillers and number of panicles were highest with lower dilutions (1:1 & 1:5) of spent wash compared to higher dilutions (1:20 and 1:40). Plants with five times diluted spentwash were significantly taller and other growth parameters were also on higher side than those grown using spentwash of higher dilution effluent. This might be due to the increased availability and uptake of all essential nutrients in soil attributed to higher content in spent wash which might have stimulated the vegetative growth of paddy crop.

Yield parameters like number of filled grains per panicle was highest in higher dilution (1:40) and was on par with 1:20 dilution which decreased significantly with decrease in dilution levels .The decrease in number of filled grains per panicle at lower dilutions may be because of more chaffy and unfilled nature of grains. It may also be due to application of excess nutrients particularly nitrogen which increased the sterility and eventually more unfilled grains (Anon., 1971). Similar results were also made by Nagaraj (1981) and Devarajan and Oblisami (1995) who reported that higher yield attributing characters were influenced by higher dilutions of spentwash.

5.4.2 Grain and straw yield

The Grain and straw yield reflected the trend observed in yield parameters as influenced by different dilutions of spentwash (Table 4.26, Fig 5.37 & Plate 12). The grain yield of paddy increased significantly due to different dilutions of spentwash. Table and figurer number to be indicated in brackets

Application of distillery spentwash at 1:40 dilution recorded significantly highest yield followed by 1:20 dilution. Significantly lower grain yield was recorded with 1: 1dilution but was on par with distillery spentwash at 1:5 dilution. The higher grain yield at higher dilution was influenced by better expression of yield components like number of seeds/panicle and number of filled grains per panicle. These results are in confirmity with the results of Devarajan and Oblisami (1995) and Chinuswamy *et al.* (1998) who noticed that 50times diluted effluent was found to be suitable for paddy and lower dilutions were not suitable for paddy. Similar observation was made by Pathak *et al.* 1999 and Annadurai *et al*. 1999 who asserted that the paddy grain yield was increased due to application of spentwash at higher dilutions (1:50times). The significant reduction in grain yield at lower dilutions might be due to higher concentration of the effluent which

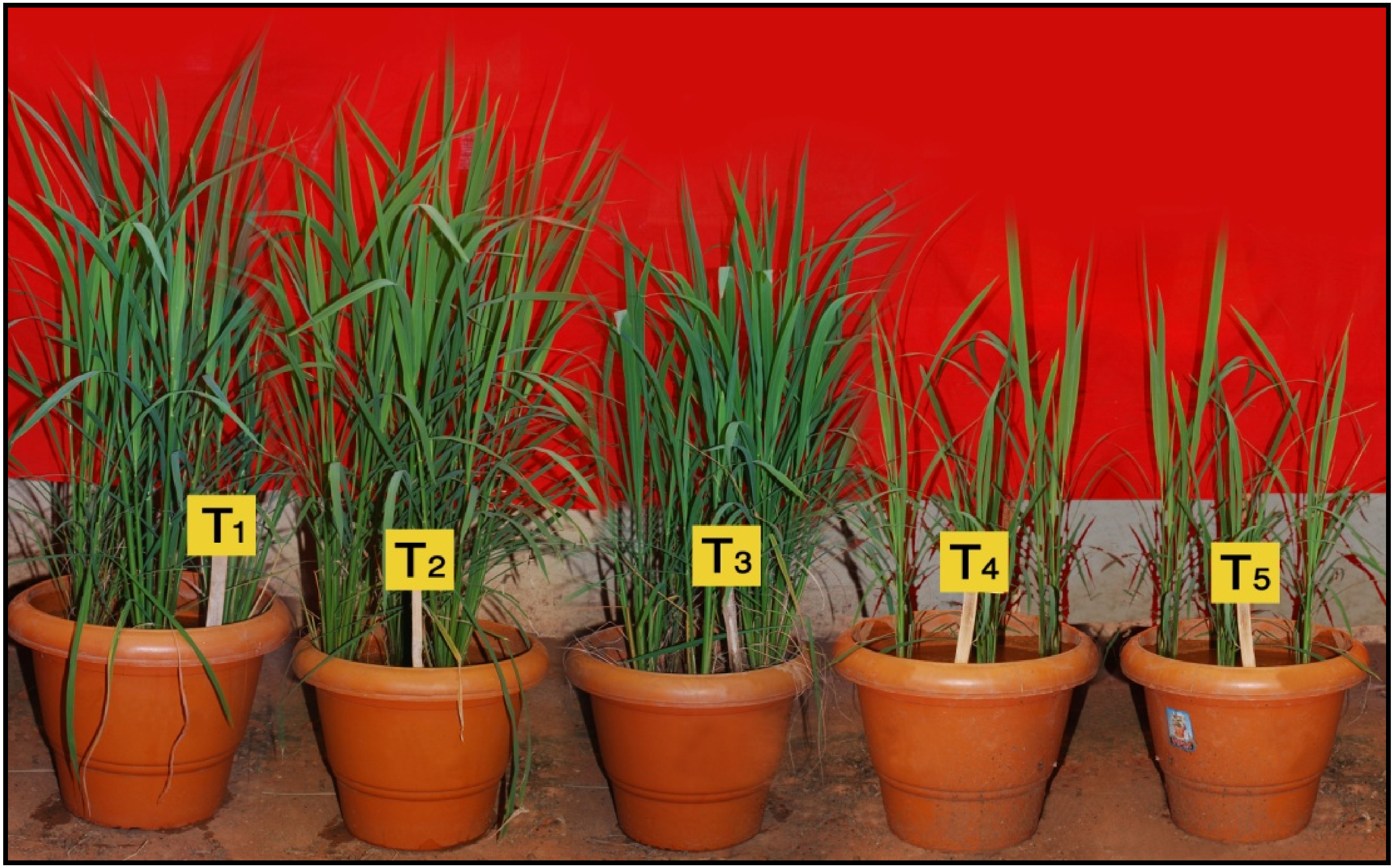

Plate 12 : Paddy crop with spentwash at different dilutions

contained excess of various cations and anions which retard growth by affecting water absorption and other metabolic processes of plants (Khosla, 1980). Further, Sahai *et al.* (1983) also reported that distillery effluent contained an excess of cations and anions which are injurious to plant growth and the concentration of these constituents should be reduced to the beneficial level by diluting the effluent. There is a greater source-sink relationship at higher dilution. Similar results have been reported by Pujar (1995).

Contrary to grain yield it was noticed that, the straw yield of paddy was significantly higher at lower dilutions. Significantly highest straw yield was recorded with 1:5 dilution and was on par with 1:1 and 1:10 dilution whereas the straw yield decreased at higher dilutions. This might be due to lower concentration of all the essential nutrients. Lowest paddy straw yield was recorded in T_5 (1:40dilution) but was on par with 1:20 times diluted spentwash. The higher straw yield and lesser grain yield in lower dilutions could be attributed to significant increase in plant height, more number of unproductive tillers and also increased nitrogen uptake supplied from effluent. Providing excess nutrients particularly nitrogen was reported to increase the total biomass. The results are in conformity with studies of Pujar (1995) who noticed that the 10 times diluted effluent increased the straw yield of wheat as compared to 50 times diluted effluent.

5.4.3 Effect of spentwash of different dilutions on nutrient uptake by paddy

5.4.3.1 Nitrogen, Phosphorus and Potassium

The dilution levels showed significant effect on nitrogen, phosphorus and potassium content at flowering stage (Table 4.27 & Fig 5.38). Whereas at harvest, nitrogen and potassium contents in grain and straw were influenced significantly by dilution levels. Though the phosphorus content was found non-significant higher values were noticed with lower dilution levels. Total uptake of nitrogen, phosphorus and potassium was significantly higher at higher dilution levels than lower ones. In general increase in the dilution of spentwash progressively decreased the nitrogen, phosphorus and potassium concentration. The contents were significantly higher at lower dilution levels due to increased availability of nutrients in soil attributed to higher content. At flowering stage, treatment receiving 1:1 diluted spentwash recorded relatively higher nitrogen and potassium concentration but was on par with 1:5 dilution and was significantly superior over other higher dilutions of distillery spentwash. Significantly lowest nitrogen and potassium concentration was recorded in T_5 (1:40 dilution).

5.4.3.2 Calcium, Magnesium and Sulfur

Calcium uptake differed significantly due to application of spentwash of different dilutions. Ca uptake was highest with 1:1 diluted spentwash followed by 1:5 dilution (Table 4.28). This might be due to the presence of appreciable amount of Ca in the spentwash, which enhanced the crop uptake and accumulation. Accumulation of higher K in treatments receiving distillery spentwash might have enhanced the Ca accumulation.

Magnesium uptake also followed a similar trend as that of calcium and highest Mg uptake was recorded at lower dilutions compared to higher dilutions. Similar reasons can be quoted for increased Mg uptake by paddy that is presence of appreciable quantity of Mg in distillery spentwash and greater accumulation of Mg with increased K.

On the contrary, highest sulfur uptake was observed with higher dilutions. The increased uptake of S in these treatments is attributed to increased uptake and accumulation of N and P and also due to the presence of appreciable quantity of S in spentwash, which might have enhanced the S uptake. Srivastava and Singh (1993) reported that N and P have positive effect on S uptake and accumulation.

5.4.4 Effect of different dilutions of spentwash on chemical properties of soil

5.4.4.1 Soil reaction, electrical conductivity and organic carbon

Soil pH differed significantly due to application of spentwash of different dilutions (Table 4.29 & Fig 5.39). Significantly higher soil pH was recorded in T_1 (1:1 dilution) compared to initial value (6.18). With increasing dilutions of distillery spentwash, soil pH decreased progressively. The results are in accordance with Machaado-de-Armas *et al.* (1994), Singh and Raj Bahadur (1998) and Pathak *et al.* (1999), who observed marginal, increase in pH of soil with application of distillery

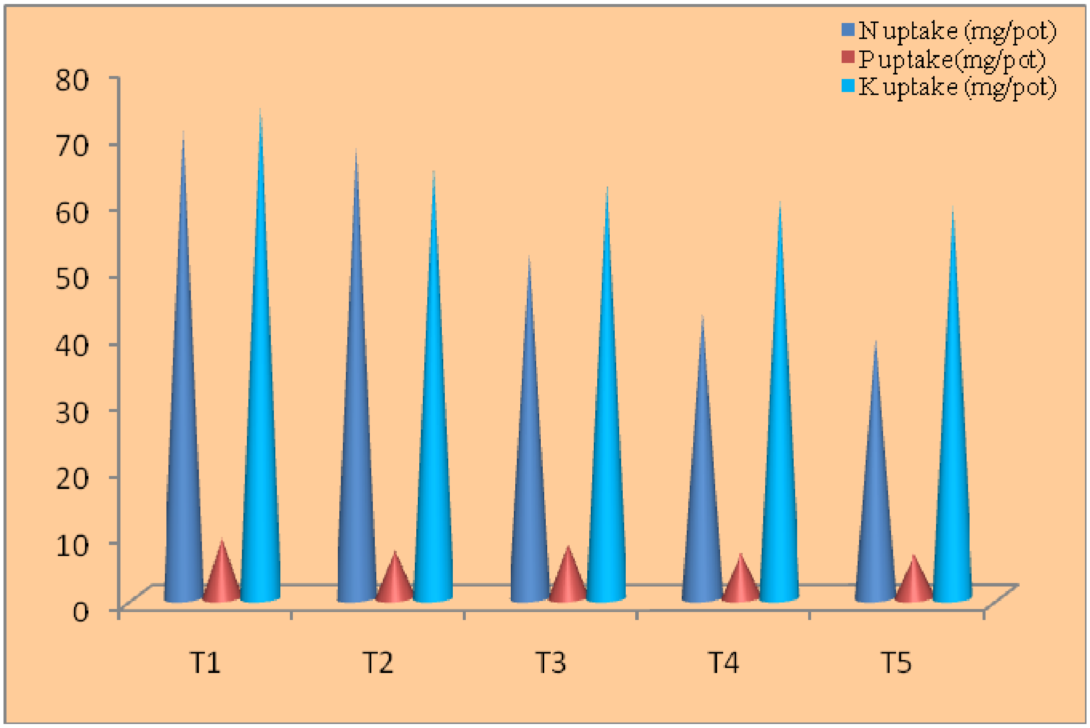

Fig. 5.38 : Effect of spent wash application of different dilutions on uptake of nitrogen, phosphorus and potassium by paddy

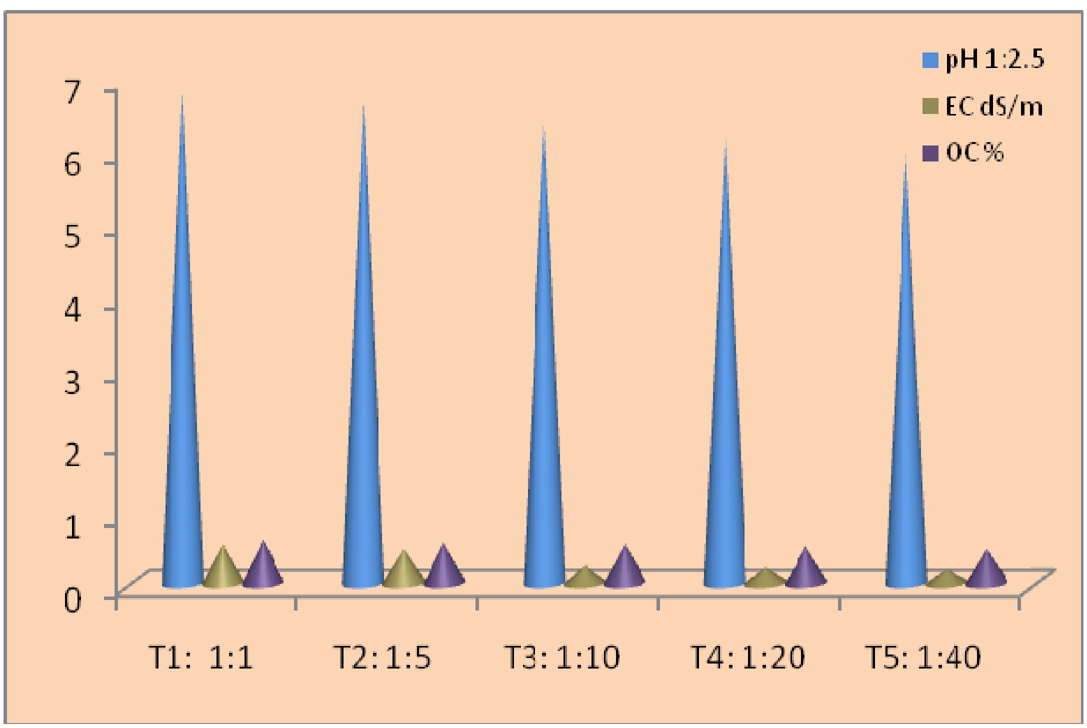

Fig. 5.39 : Effect of spent wash application of different dilutions on pH, EC and organic content of soil after harvest of paddy

spentwash. Devarajan and oblisami (1995) reported that 50 times diluted effluent recorded lower pH compared to 10 times diluted effluent and there was increase in pH of soil due to spentwash application. Increase in the soil pH could be attributed to the organic matter oxidation brought about by microbial activity (Mattiazzo and Ada Gloria, 1985).

Significantly highest EC was recorded in T_1(1:1 dilution) compared to initial value. The lowest EC value was recorded in T_5 (1:40 dilution). This is attributed to the presence of higher quantity salts in spentwash which decreased with dilution and their application to soil proportionately enhance the EC. Salt content at all stages of crop were below the thresh hold level (1.0 dS m^{-1}).With increase in dilution electrical conductivity of soil also decreased. Scandaliaris *et al.* (1987), Zalawadia and Raman (1994), Joshi *et al.* (1996) and Hati *et al.* (2005) reported increased electrical conductivity of soil with usage of spentwash.

Application of distillery spent wash in different dilutions significantly influenced the organic carbon content of soil. The highest organic carbon content was recorded in treatment with lower dilutions and decreased with higher dilutions. Significantly highest organic carbon content was recorded in T_1 (1:1dilution) but was on par with 1: 5 times diluted spentwash. Lowest organic carbon content was recorded in T_5 (1:40 times dilution). The significant increase in the organic carbon content of the soil with spentwash application could be higher due to higher organic load of spentwash. Improvement in soil organic carbon content with increase in concentration of spentwash was recorded in spentwash applied at lower dilutions.

The results are in accordance with the findings of Sweeney and Graetz (1991) who reported that application of digested distillery spentwash increased the soil constituents of most elements particularly K. The findings of Taluk and Medeirous (1989), Shinde *et al.(*1993), Zalwadia and Raman (1994) and Singh and Raj Bahadur (1998). Support the trend of results of this investigation.

5.4.4.2 Available Nitrogen, phosphorus and Potassium

Available nitrogen content of soil was significantly influenced by the application of distillery spent wash (Table 4.29 & Fig 5.40).With increasing dilutions of spent wash there was gradual decrease in available nitrogen content of soil after harvest of crop. The highest available nitrogen content of soil was recorded in T_1 which received 1:1 dilution of spent wash, which was found on par with T_2 (1:5) and was superior over other increased dilutions of spentwash.. Many researchers reported improved availability of N in soil with application of distillery spentwash (Zalawadia and Raman, 1994, Singh and Raj Bahadur, 1998, Joshi *et al*. 1996 and Sukanya and Meli, 2003, Madhusudhana, 2006).

Available P content of soil showed significant difference after harvest of crop (Table 4.29). Highest available P value was recorded in T_1 (1:1 dilution), while lowest was with T_5 (1:10 dilution). Increased available P in the soil with application of effluent was reported by Anil Kumar, 1995, Joshi *et al*. 1996, and Sukany and Meli, (2004). Ananth Kumar (2002) reported that increase in available P content of soil was due to high phosphatase activity in soil.

Significantly highest available K in soil was recorded with T_1 (1:1 dilution) over all other treatments and was on par with T_2 (1:5 dilution). Significantly lower available K was observed with T_5 (1:40). This might be due to higher concentration of potassium in spentwash.

The available N, P and K contents of the soil were also significantly influenced with effluent of different dilutions. The content of all these nutrients increased with increase in the proportion of effluent confirming the fact that the effluent contained the above mentioned nutrients in sufficient amounts (Sukanya and Meli, 2005).

Even after the harvest of crop, higher available K in soil was recorded in treatments receiving distillery spentwash. This is due to the fact that, spentwash contains substantial amount of K (1.15 per cent) which is mostly in ionic form (Kulkarni *et al.*, 1987) and becomes immediately available to plants. Also, distillery spentwash application based on the N requirement of sugarcane crop, added high amount of K,

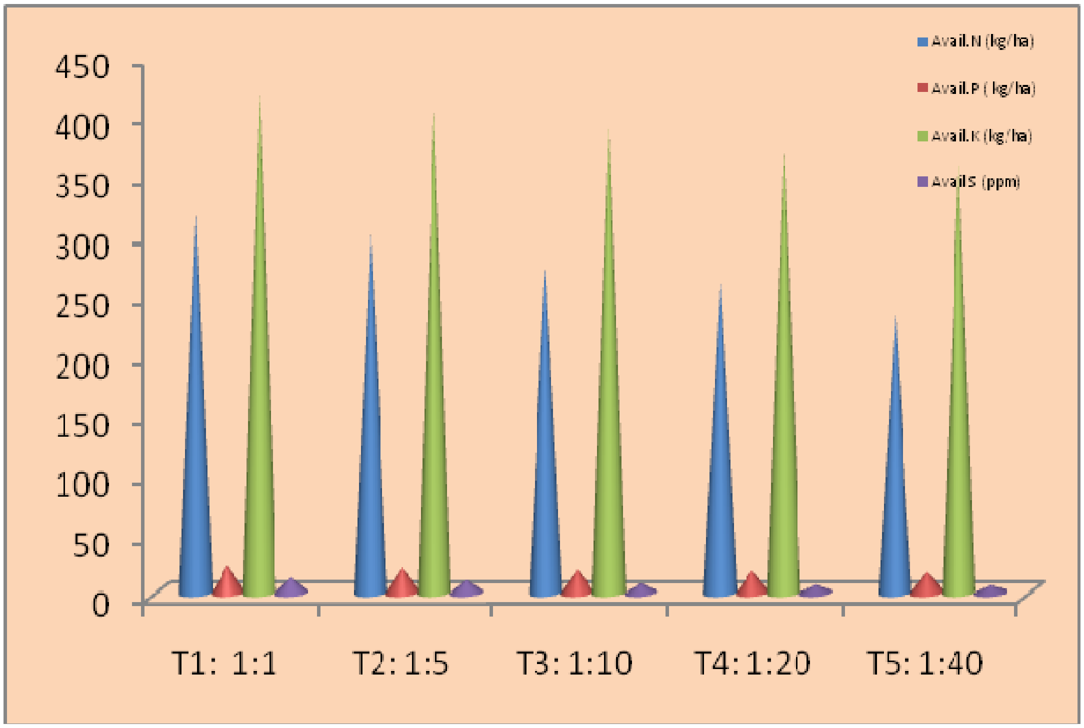

Fig. 5.40: Effect of different dilutions spent wash application on nutrient status of soil after harvest of paddy

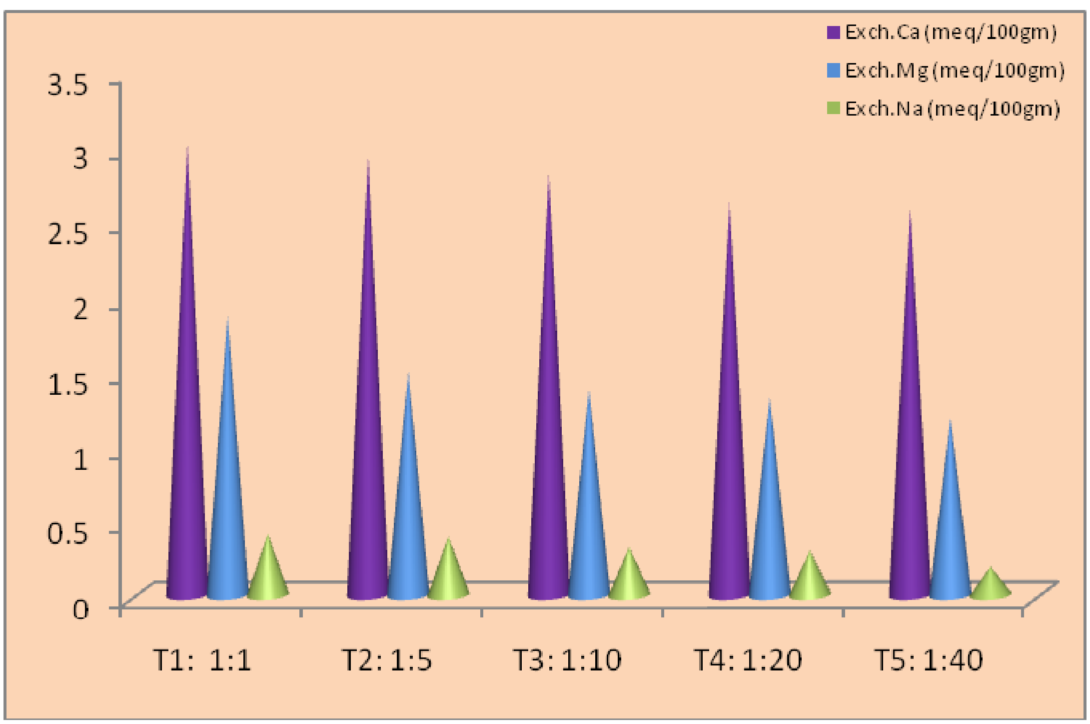

Fig. 5.41 : Effect of different dilutions spent wash application on Ca, Mg & Na content of soil after harvest of paddy

which is more than the crop's requirement and thus the excess K might have accumulated in soil. This is in conformity with the findings of Joshi *et al*. (1996), Paula *et al.* (1999), Sukanya and Meli (2003) and Suma (2006).

5.4.4.3 Exchangeable Calcium, Magnesium and available Sulfur

Exchangeable Ca and magnesium in soil after harvest of paddy was significantly influenced by application of spentwash of different dilutions distillery spentwash (Table 4.29, 4.30 & Fig 5.41). Highest exchangeable Ca and magnesium was recorded with T_1, T_2 and T_3 which received application of distillery spentwash at 1:1, followed by 1:5 and 1:10. Application of distillery spentwash 1:40 dilution recorded significantly lowest exchangeable Ca and magnesium

5.4.4.4 Exchangeable Sodium

Application of distillery spent wash in different dilutions significantly influenced the exchangeable sodium content of soil (Table 4.30 & Fig 5.41). Exchangeable Na content of soil increased due to application of spentwash. The highest exchangeable sodium content was recorded in treatment with lower dilutions and decreased with higher dilutions.The present result is in accordance with Anil Kumar (1995) and Murugaragavan (2002), who noticed marginal increase in exchangeable Na content of soil due to application of spentwash.

5.4.4.5 Micro-nutrients content of soil

Data on DTPA-Fe, Mn, Zn and Cu content of soil as influenced by application of spentwash of different dilutions indicate that increasing dilutions of distillery spentwash (Table 4.30) progressively decreased the DTPA extractable micronutrient contents of soil. Highest DTPA extractable micronutrient contents were observed with T_1 and lowest was observed with T_5 (1:40 dilution).These results are in agreement with the findings of Taluk and Medeirous (1989, Shinde *et al*. (1993), Zalwadia and Raman (1997) and Singh and Raj Bahadur (1998).

5.5 Cost economics

5.5.1 Cost economics of reclamation of sodic soil using raw spentwash and gypsum

The highest gross return and benefit: cost ratio (39241Rs.ha^{-1} and 2.97, respectively) were recorded in raw spentwash @ 5.0 lakh liters ha^{-1} + balance of P through fertilizers (T_4) due to higher grain and straw yield indicating the higher degree of reclamation and favorable nutrient supply to rice in addition to reduced cost of cultivation and least gross return (14981 Rs. ha^{-1}) was recorded with recommended NPK (without amendment) (T_1) and least benefit cost ratio (0.58) with gypsum @100% GR + recommended NPK (T_2) may due to highest cost of cultivation. (Table. 4.31).

5.5.2 Cost economics of ferti- irrigation of primary spentwash

The highest gross return and benefit: cost ratio (33407 Rs.ha^{-1} and 2.69, respectively) was recorded in raw spentwash @ 100% GR+100% RDN through SW 3splits) (T_9) due to higher grain and straw yield indicating favorable nutrient supply to rice in addition to reduced cost of cultivation and least gross return (22371 Rs. ha^{-1} and 0.53, respectively) was recorded with gypsum @100% GR + recommended NPK (T_2) may due to highest cost of cultivation. (Table. 4.32).

SUMMARY

VI. SUMMARY

The present investigation "Utilization of spentwash for reclamation of sodic soil and ferti-irrigation studies in Rice" was carried out during 2007-09. This included a pot experiment at GKVK to study the extent of reclamation of sodic and calcareous sodic soils upon use of gypsum and raw spentwash and subsequently the growth and yield of paddy. Based on the result obtained, a field experiment was conducted at VC farm, Mandya to study the extent of reclamation of sodic soil with various level of raw spentwash and inturn the growth and yield of paddy. In the same experiment plot piezometer study was conducted. Second green house experiment was conducted at GKVK on ferti-irrigation studies with spentwash and based on the result obtained; the second field experiment was conducted at VC farm, Mandya. Also another green house experiment was conducted at GKVK to study the effect of different dilutions of spentwash application on growth and yield of paddy and on soil properties. Brief summary of this investigation is presented here,

1. Characterisation of distillery spentwash

The chemical composition of raw and treated distillery spentwash samples collected from M/s Chamundeshwari Distilleries Private Limited, K.M.Doddi, Maddur Taluk, Mandya district revealed that raw spentwash is highly acidic (pH 4.11), with the electrical conductivity of 17.70 dS m^{-1}. The concentration of nitrogen, phosphorus and potassium were 0.19, 0.03, and 0.88 per cent respectively and also has good amount of calcium, magnesium and sodium content of 2600, 1700, 300.80 mg L^{-1} respectively.

The primary treated spentwash was neutral in reaction (pH 7.22) with the electrical conductivity of 8.89 dS m^{-1}. The nitrogen, phosphorus and potassium content of primary treated spentwash was 0.17, 0.031 and 1.06 per cent and calcium, magnesium and sodium content of 1759.0, 1285.0, 1093 mg L^{-1} respectively. The average concentration of iron, manganese, zinc and copper were 21.9, 6.61, 2.5 and 4.03 mg L^{-1} respectively.

Green House Experiment I

- Green house experiment was conducted to study the extent of reclamation of sodic and calcareous sodic soil upon use of RSW and gypsum. Application of rawspentwash @5.0 lakh liters ha^{-1} significantly reduced the pH, exchangeable sodium and ESP of soil at 30 and 60 days after application and the reduction was marginal there after upto 120 days after application. Application of gypsum @ 100% GR had similar effect in reducing the soil pH and ESP as that with application of raw spentwash @ 2.5 lakh liters ha^{-1}.
- Electrical conductivity of soil was highest in the treatment which received 10.0 lakh liters ha^{-1} followed by 7.5 lakh liters ha^{-1} at 30 days and there after it decreased gradually in all the spentwash amended pots.
- At 30days after application, exchangeable Ca +Mg content of soil increased with the increased levels of raw spentwash. Application of raw spentwash at 5.0 lakh liters ha^{-1} increased exchangeable Ca compared to gypsum.
- Application of raw spentwash at different quantities significantly decreased the exchangeable sodium content of both the soil. The lowest exchangeable sodium content for both the soil was recorded in treatment T_5 which received 5.0 lakh liters ha^{-1} and was on par with T_6 (7.5 lakh liters ha^{-1}).
- Application of raw spentwash at different quantities significantly reduced the ESP of both the soil. The lowest exchangeable sodium percentage for both the soil was recorded in treatment T_5 which received 5.0 lakh liters ha^{-1} and T_6 (7.5 lakh liters ha^{-1}).
- Application of raw spentwash at different quantities significantly decreased the $CaCO_3$ content of soil. The lowest $CaCO_3$ content for both the soil was recorded in treatment T_7 which received 10.0 lakh liters ha^{-1} and T_6 (7.5 lakh liters ha^{-1}).
- Increasing quantities of rawspentwash application significantly increased the pH, EC, HCO_3^-, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+} and Na^+, in leachate samples. Salt concentration in the leachate increased with increasing levels of raw spentwash. Application of raw

spentwash @10.0 lakh liters ha^{-1} recorded significantly higher values compared to gypsum amended plots.

- Among the anions, HCO_3^{-} 1, Cl^{-} , SO_4^{2-}, leached in higher quantities than other. In general, anions concentration increased with greater quantity of raw spentwash application and decreased with increase in different days after application. Among cations, Na^{+} leached was more compared to Ca^{2+} and Mg^{2+}.

Field Experiment I

- Growth and yield parameters of paddy crop differed significantly with rawspentwash and gypsum application for reclamation of sodic soil at VC Farm Mandya. Application of raw spentwash @ 5.0 lakh liters ha^{-1} recorded significantly higher values and was on par with treatment receiving 7.5 lakh liters ha^{-1}. Applications of gypsum @ 100%GR recorded on par values with raw spentwash applied @ 2.5 lakh liters ha^{-1} and were significantly superior over Rec.NPK (no amendment). Computation of cost economics clearly indicated highest benefit cost ratio of 2.97 was recorded with raw spentwash @ 5.0 lakh liter ha^{-1} and the lowest (0.58) was with gypsum at 100% GR+Rec.NPK
- Paddy grain and straw yield were significantly influenced by raw spentwash and gypsum application. Highest grain yield was recorded in raw spentwash @ 5.0 lakh liters ha^{-1} and was on par with 7.5 lakh liter ha^{-1}. Highest straw yield was recorded in 7.5 lakh liters ha^{-1} followed by 5.0 lakh liters ha^{-1} and 2.5 lakh liters ha^{-1} whereas control and gypsum amended treatments recorded lowest straw yield compared to rawspentwash amended plots.
- Major, secondary and micronutrient uptake by paddy differed significantly due to raw spentwash and gypsum treatments. Total uptake of all these nutrients were highest in treatment receiving raw spentwash @ 7.5 lakh liters ha^{-1} followed by raw spentwash applied @ rate of 5.0 lakh liters ha^{-1}.
- Chemical properties of soil differed significantly due to application of raw spentwash. Reduction in soil pH was maximum in treatment receiving 5.0 lakh liters ha^{-1} followed by 7.5 lakh liters ha^{-1}. Electrical conductivity of soil was highest in raw

spentwash applied plots compared to gypsum. Organic carbon content of soil also differed significantly due to application of raw spentwash compared to treatments receiving gypsum and Rec.NPK.

- Available nitrogen, phosphorus and potassium content of soil varied significantly due to raw spentwash application. Highest content of all these nutrients in crop were recorded at tillering stage and as the stage advanced there was gradual decrease after the harvest of paddy.
- Exchangeable calcium, magnesium and sodium contents of soil also varied significantly due to different levels of raw spentwash. Highest exchangeable calcium and magnesium was recorded in treatment receiving 5.0 lakh liters ha^{-1} followed by 7.5 lakh liters ha^{-1}. Reduction in exchangeable sodium was highest in treatment receiving 5.0 lakh liters ha^{-1} which was significantly superior over treatments receiving gypsum and Rec.NPK (no amendment).

II Ferti-irrigation Studies in Paddy

Green house Experiment II

- The plant height, number of tillers, number of panicles, and number of seeds per panicle were higher with application of spentwash. Growth parameters at harvest of paddy crop were highest with distillery spentwash ferti-irrigation at 150 per cent RDN. All the treatments, which received the spentwash application, responded well than treatments receiving only chemical fertilizers.
- The grain and straw yield of paddy reflected the trend observed in various growth and yield parameters as influenced by ferti-irrigation of DSW. Grain yield was increased significantly due to ferti-irrigation of spentwash. Highest yield was noticed with application of DSW 150% RDN (in 33% in each irrigation) followed by 150% N through urea in (33% in each irrigation) and RDF (NPK) + FYM.
- Application of 150% RDN through DSW (33% in each irrigation) recorded highest uptake of nitrogen, phosphorus potassium and sulfur.

- Soil reaction differed significantly due to DSW application compared to chemical fertilizer applied plots. Significant increase in pH was observed in treatments, which received DSW application.
- Application of DSW marginally increased the EC after the harvest of crop when compared to RDF treatments. Ferti-irrigation of DSW, significantly increased the OC content of soil. After harvest of crop, highest OC was noticed in DSW applied and RDF + FYM treatments.
- Available P in soil did not differ significantly due to application of DSW. However, marginal increase in available P was noticed in treatments receiving DSW application compared to RDF. Ferti-irrigation of DSW at 150 per cent RDN and at 100 per cent RDN significantly increased available K which were superior over RDF.
- Exchangeable Ca and Mg differed significantly due to spentwash application after the harvest of crop. Ferti-irrigation of DSW at 150 per cent RDN recorded higher Ca and Mg contents of soil than at 100 per cent RDN level. Exchangeable Na content of soil differed significantly due to ferti-irrigation of spentwash. Ferti-irrigation of DSW at 150 per cent RDN accumulated slightly higher sodium compared to RDF and RDF+FYM.

Field experiment II

- Grain yield increased significantly due to ferti-irrigation of spentwash on reclaimed sodic soil. Highest grain yield was recorded in RSW @ 100% GR+100% RDN through SW (3splits) and lowest grain yield was recorded in T_1 which received Gypsum @50% GR + Recommended NPK.
- Total uptake of nitrogen phosphorus and potassium were significantly influenced by ferti-irrigation of spentwash. Highest uptake was recorded with treatment receiving (RSW @ 100% GR+100% RDN through SW (3splits).
- Application of spentwash significantly influenced the calcium, magnesium and sulfur uptake in paddy, recording highest in treatment receiving (RSW @ 100% GR+100% RDN through SW (3splits) and significantly lowest uptake was recorded in T_1 which received gypsum @50% GR+Rec.NPK.

- Soil pH differed significantly due to ferti-irrigation of spentwash application. Reduction in soil pH was highest in T_9 (RSW @ 100% GR+100% RDN through SW (3splits)) and lowest in T_1 (Gypsum@50% GR+ Rec.NPK). Ferti-irrigation of spentwash significantly increased the electrical conductivity (EC) of soil. Increase in soil EC was more in spentwash amended plots compared to gypsum applied plots. Significant accumulation of OC in soil was noticed in RSW @ 100% GR+100% RDN through SW (4splits) which was significantly superior over T_1 and T_2 which received gypsum @50% GR and 100% GR respectively.
- Available N, P, K content of soil at different crop growth stages of paddy was significantly influenced by ferti-irrigation of spentwash. At tillering stage, ferti-irrigation of spentwash significantly influenced available nitrogen content of soil. Higher amount of nitrogen was recorded in spentwash amended plots compared to gypsum application.
- Exchangeable Ca and Mg differed significantly due to spentwash application after the harvest of crop. Significantly highest amount of these available nutrients was recorded in T_{10} RSW @ 100% GR+100% RDN through SW (4splits) and was significantly superior over RSW @ 50% GR and 100 and 150% RDN through spentwash.
- Exchangeable Na and ESP of soil differed significantly due to ferti-irrigation of spentwash. Application of RSW @ 100% GR+100% RDN through SW (4splits) recorded significantly lower sodium content and ESP compared to other treatments.
- The cost economics of cultivation revealed that highest benefit cost ratio (2.69) was obtained with raw spentwash @ 100% GR+ 100% RDN through treated spentwash in 3 splits while the lowest 0.53 was with gypsum @ 100% GR+ rec.NPK.

Green house experiment III

- Growth parameters viz., plant height and number of tillers, number of panicles, and number of filled grains per panicle were increased significantly due to application of spentwash in different dilutions. Plant height, number of tillers and number of panicles were highest with lower dilution (1:1 & 1:5) of spent wash compared to higher dilutions (1:20 and 1:40).

- Application DSW at 1:40 dilution recorded significantly highest yield followed by 1:20 dilution. Significantly lower grain yield was recorded with 1: 1dilution but found on par with DSW at 1:5 dilution.
- The dilution levels showed significant effect on nitrogen, phosphorus and potassium content at flowering stage. Whereas, at harvest nitrogen and potassium contents in grain and straw were influenced significantly by dilution levels. Though the phosphorus content was found non-significant, higher values were noticed with lower dilution levels. Total uptake of nitrogen, phosphorus potassium was significantly higher at higher dilution levels than lower ones.
- Soil pH differed significantly due to different dilutions of DSW. Significantly higher soil pH was recorded in T_1 (1:1 dilution) compared to initial value (6.18). With increasing dilutions of DSW soil pH decreased progressively. Significantly highest EC was recorded in T_1 (1:1 dilution) compared to initial value. The lowest EC value was recorded in T_5 (1:40 dilution).
- With increasing dilutions of spentwash there was gradual decrease in available NPK content of soil after harvest of crop. The highest available NPK content of soil was recorded in T_1 which received 1:1 dilution of spent wash, which was found on par with T_2 (1:5) and was superior over other increased dilutions of spentwash.
- Highest exchangeable calcium and magnesium content was recorded with T_1, T_2 and T_3 which received application of DSW at 1:1, followed by 1:5 and 1:10. Application of DSW 1:40 dilution recorded significantly lowest exchangeable Ca and magnesium.
- DTPA-Fe, Mn, Zn and Cu content of soil was also significantly influenced by different dilutions of DSW. However, with the increasing dilutions of DSW progressively decreased the DTPA extractable micronutrient contents of soil.

Conclusion

The raw distillery spentwash a waste water discharged by distilleries can be utilized as a nutrient rich resource for reclamation of sodic and calcareous sodic soil. Also, the enormous quantities of plant nutrients present in spentwash offers an excellent opportunity to use it as a liquid fertilizer along with irrigation water, thus enabling the farmers to save on fertilizers and at the same time achieve higher yields of crops.

Future Line of work

1. More efforts are needed to ascertain the long term impact of rawspentwash irrigation on soil health and crops
2. There is a need to work out rawspentwash application rate for different soils with varying degree of sodicity and calcium carbonate content.
3. Different crops respond differently to diluted distillery effluent irrigation. Hence screening of major crops for suitability to distillery effluent as irrigation source on growth and yield would be useful.
4. In depth study is to be carried out on quality parameters of crops over continuous use of diluted distillery effluent irrigation should be evaluated

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*Originals not seen