

**EFFECT OF UGAR SUGAR DISTILLERY EFFLUENT
IRRIGATION ON SOIL PROPERTIES AND CROP YIELD**

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BY

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CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF UGAR SUGAR DISTILLERY EFFLUENT IRRIGATION ON SOIL PROPERTIES AND CROP YIELD" submitted by Mr. ANILKUMAR S. HALLAD for the degree of MASTER OF SCIENCE (AGRICULTURE) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY, of the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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January, 1995

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Dedicated
To
My Father
Late
Shri. Shiddalingappa Hallad

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INTRODUCTION

I . INTRODUCTION

Water is one of the most valuable resources available to man for his domestic and industrial uses. Growth of population, massive urbanization, rapid rate of industrialization and inculcation of modern technology in agriculture and animal husbandry have accelerated water pollution and have lead to gradual deterioration of its quality. The wastes or effluents of the factories from urban areas are largely disposed off in rivers, streams and lakes, which are chief sources of water for agriculture, industries, aquatic life and for domestic purpose.

Waste water renovation and reuse technology has today become a major area of interest to engineers, biologists, chemists, agronomists, public health officers and water resource authorities. Their concern is to prevent pollution of surface water and develop additional water resources for agriculture, industry, or urban uses as well as the protection of public health.

The effluent being discharged from various factories, contains large quantities of soluble salts, heavy metals and possess higher BOD and COD values and varying pH. Therefore direct disposal of such harmful effluents in natural water ways pose severe problems not only to the aquatic life and crop plants but also affects the life of people living in the

downstream areas. Treatment of effluent before discharging into natural water streams is a very costly process. Alternate method for safe disposal of such effluents is the need of the day.

Recent regulations governing waste water discharge into surface water and increasing cost for waste water treatment have encouraged the development of irrigation system for recycling of waste water in crop production. Land application of waste water is one of the most economically and ecologically viable methods (Thomas and Law, 1968).

Quality of water for irrigation is decided by its composition, the types of crops grown, soils, climate and agronomic practices (Lyerly and Longenecker, 1962). The usual criteria for quality of irrigation are salinity, sodicity and toxicity of certain chemicals to crops. The presence of higher concentration of sodium and other harmful elements in the effluent may cause adverse effects on physical and chemical characteristics of the soil when effluents are used for irrigation.

The effect of sugar factory and distillery effluent on growth and yield of crop plants and on soil properties has not been extensively studied. Hence a study was conducted using the distillery effluent of ugar sugar factory, Ugarkhurd as a source of irrigation under different dilutions and amendments

for maize, wheat and sugarcane crops with the following objectives.

1. Effect of sugar factory and distillery effluent irrigation and amendment on uptake of nutrients and yield of wheat, sugarcane and maize.
2. Accumulation of salts and exchangeable cations, water soluble cations and anions at different depth of soil column leached with different effluent river water ratios in presence of amendments.
3. To study the available major and secondary nutrient status of the soil irrigated with different ratio's of distillery effluent : Krishna river water.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

The literature pertaining to the nature of pollution caused by spentwash, water pollution, characteristics of different effluents, land disposal of waste water, water quality specifications, effect of effluent on soil properties, crop growth and use of gypsum as amendment to reduce sodium hazards are reviewed here.

2.1 Nature of pollution caused by spentwash

Polluting effects of spentwash are mainly due to higher concentration of readily decomposable organic matter through biological activity as a consequence of which its discharge into surface water cause deoxygenation and loss of aquatic life. It is no more fit for human consumption. As spentwash is rich in highly putricible organics, the waste water as it flows through water stream decomposes rapidly giving obnoxious odour. This odour is nuisance and makes the environment filthy and life of people living nearby distinctly miserable. The discharge of spentwash into natural stream of water causes increase in organic load, lowering the pH of waste water, depletion of oxygen content and subsequently destruction of aquatic life etc. while discharge on land causes pollution of subsoil, water, accumulation of toxic substances, changing vegetation and crops, unpleasant smell and so on. (Patil *et al.*, 1987).

2.2 Water pollution

Water pollution may be defined as process of contaminating a medium with impurities of less desirable level of quality " (Dewtlyer, 1971). But Clark *et al.* (1977) defined "pollution as presence of any foreign substance (organic, inorganic, radiological or biological) which tends to degrade quality and constituents a hazard or impairs the usefulness of water".

Waste water contains objectionable amounts of BOD, COD, dissolved solids, suspended solids, chlorides and sulphates of sodium, calcium etc. When such an effluent is let into river or natural body of water, it results in pollution of water. Industrialization has its inevitable effect on pollution of air, water and soil based on type of industry, nature of raw material used and manufacturing sources involved. Water can often purify itself biologically, but not if it is overloaded with pollutant.

2.3 Water quality specifications

The quality of irrigation water is important in judging its suitability for irrigation. The quality of water is generally expressed on the basis of

1. Total salt concentration
2. Relative proportion of sodium to other cations.

3. Boron concentration
4. BOD and COD.
5. Carbonates and bicarbonates.

Hilgard (1906) was among the first to recognise the importance of quality water.

The quality of irrigation water is decided by type of crops grown, soils, climate, agronomic practices and quantity of water available (Lyersley and Longenecker, 1962). The tolerance limits for industrial effluents discharged into inland surface waters should not have BOD more than 30 mg/l. pH 5.5 to 9.0, COD and suspended solids not more than 250 mg/l and 100 mg/l respectively.

2.4 Land disposal of waste water

Land disposal of waste water is an alternative to conventionally and advanced waste water treatment in the prevention of surface water pollution. Liquid wastes commonly applied to land included conventionally treated sewage, wet sewage sludge, liquid animal waste and effluents from fruit or vegetable processing plants, dairies and pulp and paper industries.

Land application of waste water is one of the most economically and ecologically viable method (Thomas and Law, 1968). Waste water has been used as a source of irrigation

water and plant nutrients to grow grass, shrubs, trees and flowers (Hirsch, 1969).

Land application of waste water from food processing, pulp, paper and dairy industries has been practiced extensively (Sullivan, 1973). Wilcox (1959) indicated that effluents from paper, pulp and other processing plants are well suited for land disposal.

Gellman and Blosser (1959) felt that the paper mill wastes could be safely disposed by land irrigation although sodium desorption and damage of structure were problems.

The microbiological investigations by Ravishankar (1977) indicated the possibility of using the waste water from pulp mill for irrigation. Satyanarayana Rao (1980), suggested that by proper treatment and good management, the paper mill effluents can be used for farming purposes. It has also been pointed out that paper mill effluent can be treated with cheap chemicals like gypsum and thus made safer for using the effluent for irrigation of field crops. (Deshpande, 1975).

Application of waste water from processing industry to agricultural land may help for the growth of crops, conserve water and nutrients otherwise wasted, provide economical treatment of the waste water and decrease the pollution on surface water (Thomas and Law, 1968).

2.5 Characteristics of industrial effluents

2.5.1 Characteristics of spentwash

Deshmane (1975) stated that spentwash solids contained relatively more quantities of arabinose, galactose, fructose, glucose and xylose. The spentwash solids contained more inorganic nitrogen and less unhydrolysable nitrogen than FYM.

Savant *et al.* (1980) studied chemical nature of spentwash solids (SWS) and FYM and reported that SWS contained more ether soluble, alcohol soluble and hot water soluble fractions than FYM, SWS contained more of inorganic nitrogen and less hydrolysable nitrogen than FYM, while it was poor source of total as well as organic and inorganic phosphorous as compared to FYM. The total potassium content of SWS was about 12 times more than FYM.

Guruswamy (1986) reported that spentwash as it leaves distillation unit will have a temperature of 9°C with a smell of burnt sugar. The colour of spentwash is somewhat reddish brown to dark brown. Spentwash is highly acidic with a pH between 3.5 to 4.5. It contains high percentage of dissolved inorganic and organic matter. The latter being particularly responsible for high BOD and polluting nature of waste. In general, potash content ranges from 7 to 15 per cent of total solids.

Kulkarni *et al.* (1987) stated that spentwash is major pollutant because of its high organic contents. The high BOD caused depletion of dissolved oxygen and proved very harmful to aquatic life. They classified spentwash as dilute liquid organic fertilizer with potassium content and further reported that it contained about 90 to 93 per cent water and 7 to 10 per cent solids. Seventy five per cent of solids were organics and 25 per cent inorganics. Its nitrogen was mostly in colloidal form, behaving as a slow release nitrogen fertilizer, better than most inorganic nitrogen sources. The two third of phosphorus was also in organic form. The metabolic availability of which was more than any inorganic source. Moreover, it contained large amount of such important secondary elements such as calcium, sulphur and magnesium as well as trace elements such as copper, manganese and zinc. It contained 29.06, 11.0, 9.0, 1.5, 21.0, 4.5, 5.5 and 15 per cent mineral matter, reducing sugars, protein, volatile solids, gum, combined lactic and combined organic acids, glycerol and phenolic bodies, respectively.

Patil *et al.* (1987) indicated that spentwash was highly acidic and carried a huge organic load and total solids. It contained good amount of potassium and high concentration of chlorides and sulphates. Besides, it was highly viscous and corrosive type of liquid.

Kulkarni *et al.* (1990) pointed out the presence of sugars (2 to 20 per cent) and proteins (10. to 11 per cent) in the dry spentwash along with mineral component.

2.5.2 Characteristics of other industrial effluents

Pearson (1972) analyzed fruit processing wash water for total salt content, ionic concentration and organic matter to assess their suitability for irrigation. He observed high COD value and excessively high concentration of sodium and chloride. The sodium and chloride ions in waste waters were due to brine solution used in quality grading process.

Gupta and Mozumdar (1973) noticed the presence of organic acids, phenols, some inorganic and neutral compounds which are toxic to plants and animal life in spent liquors from coak oven section of steel plants.

Balakrishna Rao *et al.* (1977) have studied waste water from sugar industry, acetate factory, textile mills and breweries for various parameters and reported that most of effluents were acidic in nature and had high total solids, BOD and COD. A high concentration of dissolved solids, ammonia, Urea, Sulphate, Phosphate, Fluoride, with low concentration of BOD and COD were observed in the effluent from fertilizer factory producing ammonia, Urea and Phosphate group of fertilizers. Waste water of pharmaceutical company had high amount of total dissolved solids, sodium, chloride and high COD.

Pescod and Thanh (1977) described the waste water of tapioca starch industry as highly organic containing low concentration of nitrogen and phosphorus and pH values ranged from 3.8 to 5.2. The cause of pH variation was attributed to addition of H_2SO_4 in the extraction process and release of some prussic acid by tapioca roots. Agarwal and Kumar (1978) obtained lower BOD and COD values and traces of phosphorus and nitrate from chemical factory effluent.

Murahari Rao *et al.* (1978) pointed out that waste water produced during mango processing season was stronger (2205 mg/l of BOD, 4410 mg/l of COD and 1120 mg/l of suspended solids) than waste water produced during tomato processing season (260 mg/l of BOD and 1970 mg/l of COD) in mango and tomato processing plants and both the waste waters were deficient in nitrogen and phosphorus.

Verma *et al.* (1978) made a survey of sugar factories in western UP and analyzed sugar mill wastes. Mixed wastes of different factories contained high BOD (805 to 1660 mg/l) and COD (1011 to 2236 mg/l) respectively. Besides, good amount of oil and grease content (16 to 54 mg/l).

Rajanan and Obliswamy (1979) reported that effluent samples from paper factories were alkaline and contained considerable amount of nitrate nitrogen (313 to 368 mg/l). Seshasayee paper and Board mill effluent contained larger

amount of suspended and dissolved solids resulting in higher BOD and COD. Total phenols was in extremely higher concentration in the effluent from Amaravathy. So also components of carbonates, bicarbonates and sulphates were high in Amaravathy factory effluents whereas calcium, magnesium and chloride concentrations were very high in Seshasayee factory effluent. They quoted that such type of variation in the constituents of effluents might be due to different types of raw materials employed as well as effluent treatment methods adopted by companies.

Kamalam and Raj (1980) stated that tannery effluent is highly coloured and foul smelling with EC of 3.2 mmhos/cm and pH 7.8. The suspended and dissolved solids were 328 mg/l. It also contained considerable amount of chlorides of sodium, magnesium and sulphate of magnesium which are known to be harmful for plant growth. The BOD and COD were high (752 mg/l and 4600 mg/l respectively).

Shrinivasamurthy (1983) indicated that effluent of Mysore paper mills, Bhadravati was light brown to dark brown in colour, bad smelling and contained high amounts of suspended solids (933.6 mg/l) and dissolved solids (948.3 mg/l). BOD of this effluent was less than ISI limit prescribed for land irrigation. The pH ranged from 6.2 to 10.9 and electrical conductivity from 560 to 1400 mmhos/cm. It was high in sodium (6.1 me/l). The concentration of major nutrients were low.

Somashekhar *et al.* (1984) studied four industrial effluents namely Mandya National Paper, Kasturi paper, food and chemicals, Ideal Jawa Ltd. and K.R. mills, Ltd. They pointed out that pH of all the effluent samples is on the alkaline range. The oxidizable organic matter content of all the factories is very high except Ideal Jawa Ltd. The effluents of all the factories except Ideal Jawa contained variable amounts of nitrate nitrogen. The ammonical nitrogen content of Mandya paper mills was more than 3000 ppm. The effluent of KFC Ltd. contained objectionable amounts of chloride. The sulphate content of the effluents of all the factories remained below ISI standard (IS 3307, 1965). The BOD values of all factories except Ideal Jawa exceeded the limit stipulated by ISI. The effluent from Mandya paper mills contained lot of suspended solids.

Recault (1990) reported that vinasse was rich in potassium and contained small amount of nitrogen and phosphorus.

2.6 Effect of effluent on soil properties

In recent years, use of soil system for disposal of effluent has been engaging much importance because of the dual advantage of using it both for crop production and for disposing the effluent. But it can be said that direct disposal of effluent to natural waterways or soil system can no

longer be allowed due to their pollution effects. Alternatively, it can be used for irrigating the crops after giving suitable treatments and bringing the composition well within the tolerance limits accepted for irrigating waters in agriculture or it can be irrigated on soil treated with suitable soil amendments. It is generally desirable to remove as much suspended materials from waste water as possible before water is applied to land, because clogging from excessive accumulation of suspended solids on the surface of the soil can cause problems on disposal of effluents to the field with poor drainage.

Blosser and Owens (1964) reported that irrigation of paper mill effluent causes dispersion of soil aggregates when SAR of paper mill effluent exceeded the value of 9.0, as a result, infiltration rate was retarded. This was ascribed to sodium replacing calcium and magnesium in exchange complex. However, Ben *et al.* (1965) reported that there was no change in aggregation caused by irrigation of paper mill waste water.

Bouwar and Choney (1974) observed that in soils overloaded with organic carbon compounds due to liquid waste, there is a build-up in waste water solids and solids formed by bacterial activity under anaerobic conditions caused by high oxygen demand will in turn cause decrease in infiltration rate.

Cunningham *et al.* (1975) reported that soil electrical conductivity was increased soon after application of sewage sludge.

Jadhav and Sawant (1975) indicated that application of spentwash increased pH, EC, cations, anions, SAR, PAR, exchangeable sodium, potassium and decreased calcium and magnesium. Significant rise in COD of saturation paste extract of soil was observed. Beneficial effect on available nitrogen, phosphorus, and potassium content of soil was observed. However, they noticed adverse effect on water retention, hydraulic conductivity and water stable aggregates of soil.

Ramanathan *et al.* (1977) indicated that mechanical composition namely coarse sand and fine sand contents were considerably reduced in soil which has received sewage irrigation over well water irrigation. Sewage water being alkaline (8.5 pH) had a solubilising effect on the primary minerals and there was considerable reduction of sand fractions in sewage irrigated fields. This reduction in sand fraction also resulted in increase in clay fraction. They also indicated increase in hydraulic conductivity, non capillary porosity and aggregate stability, by sewage water irrigation. Among the analytical characteristics, total nitrogen, organic carbon contents were reduced in sewage irrigated fields. Water soluble and exchangeable sodium, total zinc, pH, EC were lower in soil with sewage irrigation than

one without sewage irrigation. Total phosphorous, potassium, available nitrogen, phosphorus, potassium water soluble calcium, magnesium and potassium and exchangeable calcium, magnesium, potassium, total copper. Iron and manganese and CEC were higher in soil under sewage irrigation.

Singh *et al.* (1980) found that addition of spentwash without dilution was very effective in increasing water intake rate of sodic calcareous soil and pH and salt content of soil decreased to a safe limit. The exchangeable sodium percentage was reduced from 100 in original soil to 2 in top 15 cm. They indicated that spentwash application followed by irrigation rather than dilution of spentwash at the time of its application was very effective in reclamation of sodic soil.

Nunes *et al.* (1981) applied increasing level of spentwash and observed that total nitrogen, carbon levels and exchangeable sodium were not affected. Exchangeable K, Ca, Mg and pH were increased while exchangeable Al, available P_2O_5 and nitrate decreased.

Camargo *et al.* (1984) found that vinasse, KCl and K_2SO_4 increased the pH of soil and enhanced nitrification.

Jayaram and Perumal (1984) stated that irrigating the soil with municipal sewage effluent over a period of 25 years and 15 years found to accumulate higher amount of organic

matter and higher concentration of Ca, Mg, Na and K. The concentration of exchangeable cations decreased with increase in depth in both sewage irrigated and sewage unirrigated fields.

Somashekar *et al.* (1984) observed that mineralization of organic material as well as nutrients present in the effluents are responsible for increase in the availability of plant nutrients.

Mattiazzo and Ada Glorida (1985) applied vinasse upto 20 years and found that soil was benefitted interms of pH increase, higher K, Ca, and Mg content and greater CEC.

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

A study of effect of sewage and tube well water irrigation on chemical properties of soils conducted by Azad *et al.* (1987) showed lower soil pH (7.9 to 8.3) amended with sewage water than that of soils (8.6 to 9.0) irrigated with tube well water. The content of organic mater, calcium carbonate, and clay was 1.18, 5.23, 13.2 per cent respectively in sewage water amended soils. The content of organic matter and clay decreased with depth, whereas calcium carbonate in general increased. The available nitrogen content of surface

soils irrigated with sewage water and tube well water was 87 and 51 ppm respectively and it decreased with depth. The available 'P' content of soil followed similar trend as that of available nitrogen. The total P and K content of sewage amended soils were more by 47 and 34 per cent respectively, than that of adjacent tube well water irrigated soils. Total 'P' content decreased with depth, whereas total 'K' content increased. The content of nutrients irrespective of depth was higher in amount in sewage water amended soils than those in tube well water irrigated ones.

Juwarkar *et al.* (1987) reported that mixing of pulp mill waste water with chlorination and hypochlorite waste water in 7:1, 4:1 and 3:1 proportion reduced the SAR from 18.8 to 11%, 6.6 and 5.3 respectively without any appreciable change in total dissolved salts. All the soil samples equilibrated with pulp mill waste water crossed the ESP limit of alkali soils. However, none of the soil samples attained the ESP limit of alkali soil when equilibrated with the waste water of SAR 6.6 and 5.3.

Betranou *et al.* (1989) reported that potassium is the component supplied in large quantities by winery and distillery effluent.

Scandaliaris *et al.* (1987) pointed out that application of spentwash to soil increased the soil nitrate availability, EC, and interchangeable potassium.

Chang and Li (1988) found that application of vinasse to main crop of sugarcane increased available potassium content of sugarcane soil and remained high even after the harvest of first ratoon.

Johnson and Ryder, (1989) suggested that spray irrigation of pulp and paper mill effluent to pasture improved pasture yield and caused increase in soil pH, Na, Ca and Mg concentration.

Taluk and Medeiros (1989) observed that increase in soil pH, available N,P,K, Ca and Mg by 80 m³ vinasse application per hectare.

Cepro and Mechado (1990) observed that irrigation to cane field with sugar factory waste water effected tendency for exchangeable calcium to increase.

Sweeney and Graftz (1991) found that addition of distillery effluent regardless of rate raised the soil pH owing to increase in soil K, Ca, Mg and Na content. Further they stated that digested distillery effluent application increased soil concentration of most elements particularly K and Na.

Totawat (1991) observed a marked build up of available metallic, cation, specially Fe, Zn and Cu to a depth of 60 cm in soils rich in clay when compared to soils low in

clay content. Use of Zinc smelters diluted effluent for irrigation has resulted in several hundred fold increase in DTPA extractable Zn in the surface layer (0-15 cm) of soil.

Pawar *et al.* (1992) found that addition of diluted spentwash decreased pH and electrical conductivity of soil. They noticed significant changes in exchangeable potassium.

Singaram (1993) conducted incubation experiment on physical properties of Typic Haplustalf under the influence of continuous application of tannery effluent with dilution ranging from 0-10 times. He reported that BD values increased irreversibly from 1.34 Mg m^{-3} in control to 1.51 Mg m^{-3} with 2 times dilution and subsequently remained on par with a value of 1.54 Mg m^{-1} in undiluted effluents. This may be attributed to twin effect of direct accumulation of large quantities of inorganic and organic materials and soil interaction of sodium with exchange complex, thereby causing defloculation effects. The undesirable effect on hydraulic conductivity also noticed.

2.7 Effect of effluent irrigation on plant growth and yield

Kotch and Bloodgood (1959) reported that the initial use of 1.2 cm per day of paper board mill waste on lucerne crop caused no obvious problems. Effects on soil mineral constituents or lucerne mineral constituents were not evaluated.

Grass yield from seed germination and irrigated for a period of almost three years with unbleached Craft effluent is equal to that irrigated with tap water (Blosser and Ownes, 1964).

Hashimoto and Yokota (1965) conducted pot culture experiment on oats and orchard grass with waste pulp liquor. Yields at first and second cutting increased markedly with increasing rate of application. At the time of sowing high rates (more than 50 kg per acre) was harmful to germination. The author suggested the use of effluent for improving yield on upland soils deficit in 'P'. Significant increase of total Mn, N, P and Mg uptake by crops over three cuttings was reported by the same authors with increasing rate of application of paper mill effluent. Increase in N and Mn uptake was attributed to the presence of readily decomposable sugars in liquor, and increase in P and Mg uptake was ascribed to lignin and tannin.

Day *et al.* (1974) reported that treated municipal waste water was an effective source of irrigation water and plant nutrients for the production of high yields of high quantity hay from wheat. Sukovaty *et al.* (1974) reported that the application of beef feed lot effluent did not affect the concentration of calcium, magnesium, sodium and potassium in the forage sorghum.

Pearson (1975) mentioned that Asparagus yield was adversely affected by the application of vegetable processing waste water with highest COD of 7144 mg/l. Smith (1976) reported that the total crop removal was about 30 per cent of nitrogen that was applied through potato processing waste water. Peanut, cotton, soybean and Corn crops were successfully grown in spent motor oil applied to soils when fertilized, especially with nitrogen. Increased nitrogen application rates increased the growth of Corn (Giddens, 1976).

Rajannan and Obliswamy (1979) reported that the undiluted paper mill effluent drastically affected the germination of rice, growth of blackgram and tomato as well as vigour index of seedlings of three crops. Though the undiluted effluent inhibited the growth of plants, the diluted effluent (25 to 50 per cent), however enhanced the growth.

Mallesappa (1979) reported that soybean produced grain yield of 1763 kg per hectare due to irrigation with paper mill effluent and was statistically on par and numerically lower than that of irrigation with river water (1811 kg per hectare). Sheshadri (1980) reported that irrigation with diluted effluent gave slightly lower grain yield in finger millet (3141 and 3250 kg per hectare respectively) when compared to irrigation with river water and with river water and effluent alternately (3488 and 3396 kg per hectare respectively). However the differences were not significant.

Satyanarayana Rao (1980) reported that the treated mill effluents performed better than raw effluent with respect to germination percentage and drymatter production of frenchbean.

Kannan and Obliswamy (1992) reported that irrigation with the combined raw effluent from paper and pulp mill reduced the germination and vigour indices of crop plants. The combined effluent after dilution did not significantly affect the germination and growth. The combined effluent after aerobic treatment in a benchscale actonated sludge system, when used for irrigation without any dilution favoured the growth of crop plants.

Totawat (1992) conducted an experiment using five dilutions of Zinc smelter treated effluent with well water for irrigation and five soil amendment treatments to raise Maize, sorghum, wheat and barley and reported that the dry matter production of maize, sorghum and barley significantly decreased when undiluted effluent was used for irrigation. However, effluent when diluted with well water and used for irrigation has improved the dry matter yield. Incorporation of phosphogypsum has increased the dry matter yield of maize and barley and lowered the level of available Fe, Mn and Zn build-up in soil.

Anjum Farooqui, (1994) reported that the composite tannery effluent contains adequate quantity of water soluble salts useful for plant growth. Twenty five per cent tannery effluent promotes the vegetative and reproductive growth and yield of lentil. However, the higher concentrations of effluent retarded the plant growth and productivity with the reduction in life span.

2.8 Gypsum as an amendment to reduce sodium hazard

The impact of salinity of waste water used in biologically based lands, recycling should be carefully considered especially with respect to the salt balance of soils in arid and semiarid regions.

The adverse effects of irrigation water possessing high proportion of sodium and bicarbonate content can be alleviated to a great extent by modifying calcium to sodium ratio in water or soil by mixing some cheap source of soluble calcium. Gypsum by virtue of its low cost and moderate solubility is appropriate for this purpose (Paliwal, 1972).

Yadav and Agarwal (1961) reported that gypsum is very effective and suitable as soil chemical amendment and for the cation exchange reactions in the replacement of exchangeable Na.

Sharma *et al.* (1979) reported that the application of gypsum supplied ready source of soluble calcium which replaced sodium from the exchangeable complex thus improving the physical condition of soil and hence plant growth.

Pavankumar (1977) reported that there was decrease in pH and exchangeable Na when the soils were profused with pulp mill effluent for six weeks whereas exchangeable calcium content of soil was increased with increase in gypsum application to soils.

Mallesappa (1979) and Sheshadri (1980) noticed that the application of gypsum at the rate of 1250 kg per hectare reduced the soil pH and exchangeable sodium content of soil which accumulated due to irrigation with paper mill effluent.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

An experiment to study the effect of diluted ugar sugar distillery effluent irrigation on soil properties, crop growth and yield during 1993-94 was initiated. The details of materials used and the methods employed in the investigation are given below.

3.1 Field experiment

3.1.1 Location of site

An experiment was conducted at Ugarkhurd on the area of Ugar Sugar Works Ltd. Ugarkhurd, taluk Athani, Belgaum district.

3.1.2 Climatic condition

An average monthly rainfall received, maximum and minimum temperatures are given in appendix - 2. The highest rainfall and maximum temperature during the course of study was 99.25 mm and 38.32°C respectively.

3.1.3 Soil of experimental site

The soil was Vertisols having pH 8.2 and EC 0.43 dS m⁻¹. at 25°C.

Cropping history of site

Crops selected during kharif 1993-94.

1. Sugarcane
2. Maize
3. Soybean

Rabi 1993-94

1. Sugarcane continued
2. Wheat followed by maize
3. Maize followed by soybean

3.1.4 Cultivation practices

Sowing and aftercare were undertaken as per the package of practices. Irrigation was given at an interval of 10-15 days with 10, and 6 cm depth of water at each irrigation for sugarcane, maize and wheat crops respectively. The crop varieties, date of sowing, number of irrigations and date of harvest are as under. The grain and straw yields were recorded after the harvest.

	Sugarcane	Maize (Rabi 1993-94)	Wheat (1993-94)
Variety	CO-671	Ganga - 5	DWR - 162
Date of sowing	6th July 1993	7th November 1993	25th November 1993
Number of irrigations	12	5	5
Month of harvest	May, 1994	April, 1994	April, 1994

3.1.5 Experimental details

The design employed for the experiment was split plot having four main treatments of effluent dilutions and four subtreatments of amendments which are replicated twice.

The layout is shown in figure 1.

main treatments	subtreatments
Effluent : Krishna river water (E : K)	Amendments
1:10	Control (C)
1:25	Gypsum (G)
1:50	Gypsum + pressmud (G + P)
0:100	Pressmud (P)

3.2 Characteristics of distillery effluent used in the study

The distillery effluent of Ugar of Sugar Factory had objectionable amounts of BOD, COD, dissolved solids and suspended solids, cations and anions as per ISI standards. The pH of the distillery effluent was highly acidic (4.03). The pH of effluent after lagooning was 7.62.

3.3 Soil column leaching studies

Soil column leaching study was conducted to know the vertical distribution of salts in soil column (Protractor, 1933).

R-I				R-II			
1:10	1:25	1:50	0:100	0:100	1:10	1:25	1:50
CM	CM	CM	CM	GSc	GSc	GSc	GSc
CW	CW	CW	CW	GM	GM	GM	GM
CSc	CSc	CSc	CSc	GW	GW	GW	GW
G+PSc	G+PSc	G+PSc	G+PSc	G+PM	G+PM	G+PM	G+PM
G+PW	G+PW	G+PW	G+PW	G+PW	G+PW	G+PW	G+PW
G+PM	G+PM	G+PM	G+PM	G+PSc	G+PSc	G+PSc	G+PSc
GW	GW	GW	GW	CSc	CSc	CSc	CSc
GM	GM	GM	GM	CM	CM	CM	CM
GSc	GSc	GSc	GSc	CW	CW	CW	CW
PSc	PSc	PSc	PSc	PM	PM	PM	PM
PM	PM	PM	PM	PW	PW	PW	PW
PW	PW	PW	PW	PSc	PSc	PSc	PSc

Fig. 1 : Plan and lay out of the experiment

1:10 (Effluent : River water) C = Control M=Maize
 1:25 (Effluent : River water) G = Gypsum W=Wheat
 1:50 (Effluent : River water) G+P = Gypsum + pressmud Sc=Sugarcane
 0:100 (River water) P = Pressmud
 Net plot size = 7m x 5m
 Gross plot size = 8m x 6m

Depthwise soil samples from 3 depths viz., 0-20, 20-40 and 40-60 cm were collected from unirrigated field for the soil column study. Initial moisture content of soil used for the study was estimated. A 250 gram of air dried soil passed through 4 mm sieve was transferred to polythene bags. Moisture content of samples was brought to 10,15, 20,25,30 and 35 per cent by spraying known quantity of water to each soil sample. The polythene bags were packed tightly and kept for a week to attain equilibrium. The equilibrated soil samples were compacted in an iron cylinder of 10 cm height and 7 cm diameter till constant height was obtained. Volume of the cylinder was calculated from its diameter and height. Density of soil was computed by oven dry weight of the soil divided by its volume. The compactibility curve was drawn by plotting BD versus moisture content. From the curve, critical moisture content was found out (24%).

Layerwise soil moistened to 24% of water was filled in PVC pipe and compacted to a density of 1.25, 1.35 and 1.45 kg per m³ in the surface (0-20 cm), subsurface (20-40cm) and 3rd layer (40-60 cm) respectively. The PVC pipe of 70 cm long 7.5 diameter holed at a depth of 20,40 and 60 cm leaving 10 cm at top for watering was used for column study.

The holes were plugged with rubber viser specially designed to plug the hole and tied with thin metallic wire. Amendments like pressmud (10.6 g), gypsum (1.04 g) and pressmud

plus gypsum (5.3 + 1.04 g) were added to the surface layers of the soil column as per the treatments as subtreatment. The effluent was mixed with Krishna river water to give different ratio of effluent : Krishna river water for leaching the soil column was the main treatments. Treatments were replicated twice. The treatment particulars are as under.

Effluent dilution I = (E : K)	Amendments (A)	Depth (D)
I1 - 1:10	C - Control	D1 - 0-20 cm
I2 - 1:25	G - Gypsum	D2 - 20-40 cm
I3 - 1:50	G + P - Gypsum + Pressmud	D3 - 40-60 cm
I4 - 0:100	P - Pressmud	

The design employed was 3-factorial RBD. The depth of irrigation given per irrigation was 10cm.

The soil columns were applied with effluent : Krishna river water for 50 times at a weekly interval with 500 ml of water. After 50 irrigations, depthwise soil samples were taken out from the holes and air dried. Air dried samples were pounded in a mortar with pestle and passed through 2 mm sieve. Samples were used for the estimation of different parameters in the laboratory.

Table 1 : Properties of soil before conducting experiment

pH	8.21
EC (dSm^{-1})	0.50
Exchangeable Na [$\text{C mol (P}^+) \text{ kg}^{-1}$]	2.17
Exchangeable Ca + Mg [$\text{C mol (P}^+) \text{ kg}^{-1}$]	52.00
OC (%)	0.65
Available N (kg ha^{-1})	274.40
Available P_2O_5 (kg ha^{-1})	20.20
Available K_2O (kg ha^{-1})	503.10
Soluble Na (me/l)	2.72
Soluble K (me/l)	0.016
Soluble Ca+Mg (me/l)	3.00
Soluble HCO_3 (me/l)	1.26
Soluble Cl (me/l)	2.40
Soluble SO_4 (me/l)	0.03

3.4 Soil chemical analysis

3.4.1 Soil sample collection and preparation

Soil samples from field experimental plots were collected from 0-22 cm depth 7 days after the harvest of all the three crops. The samples were dried at room temperature, powdered by wooden pestle and mortar to pass through 2 mm sieve. Soil chemical properties were determined by adopting the following procedures.

3.4.2 Soil reaction

Soil pH was determined in 1:2.5 soil : water suspension by adopting procedure as described by Jackson (1967) using systronic pH meter.

3.4.3 Electrical conductivity

The electrical conductivity of the soil samples was determined in the supernatant liquid of 1:2.5 soil:water suspension using conductivity bridge (Jackson, 1967).

3.4.4 Organic carbon

Organic carbon was determined by Walkley and Black's wet-oxidation method as described by Jackson (1967).

3.4.5 Available nitrogen

Subbaih and Asija's (1956) alkaline-permanganate method was employed for the determination of available N.

3.4.6 Available phosphorus

Available phosphorus was determined by Olsen's method (Black, 1965). Soil sample was shaken with 0.5 M NaHCO_3 (pH 8.5) extractant for five minutes and filtered, Phosphorus in the filtrate was determined by chlorostannous reduced molybdophosphoric blue color method using spectrophotometer at 660 nm.

3.4.7 Available potassium

Available potassium was determined by extracting soil with neutral normal ammonium acetate as described by Black (1965).

3.4.8 Estimation of exchangeable cations (of the soil column leaching study)

The exchangeable cations were determined using 1:20 soil : neutral normal ammonium acetate.

3.4.9 Calcium

Calcium in the NH_4OAC leachate of the soil was determined by versenate titration using murexide indicator as described by Jackson (1967).

3.4.10 Magnesium

The ammonium acetate extractant was titrated against

standard versenate solution using EBT indicator to estimate exchangeable calcium plus magnesium. From the difference in amounts between calcium plus magnesium and calcium alone, the amount of magnesium was determined and expressed in $\text{cmol (p}^+\text{)kg}^{-1}$.

3.4.11 Sodium

Exchangeable sodium was determined in the ammonium acetate leachate using flame photometer (Jackson, 1967).

3.5 Plant analysis

Sugarcane, Maize and Wheat plant samples collected from the field experiments were used for the estimation of N, P, K, Ca and Mg after preparing plant materials for the laboratory analysis.

3.5.1 Preparation of plant samples

The straw was powdered in a Willey mill and grains were crushed to powder in a grinder. The samples so prepared (5g) were wet digested for the estimation of P, K, Ca and Mg. The powdered plant material was predigested with 10 ml of triacid mixture containing nitric acid, perchloric acid and sulphuric acid in the ratio of 10:1:4. The digestion was continued till a colourless sticky liquid was left behind. The content was cooled and the digested material was transferred to 50 ml volumetric flask by washing with 6N HCl. The final volume

was made to 50 ml using distilled water and the solution was preserved for the estimation of concentration of phosphorous, potash, calcium and magnesium in the plant parts.

The per cent nutrient concentration were worked out for grain and straw. The total uptake was calculated using the following formula.

$$\text{Total Uptake} = \frac{\left(\frac{\% \text{ nutrient in grain}}{\text{kg/ha}} \times \text{grain yield} \right) + \left(\frac{\% \text{ nutrient in straw}}{\text{kg/ha}} \times \text{Straw yield (kg/ha)} \right)}{1}$$

3.5.2 Nitrogen

Nitrogen was estimated by microkjeldahl distillation method (Jackson, 1967).

3.5.3 Phosphorus

Phosphorus content in the plant material was determined by vanadomolybdate yellow colour method as described by Jackson (1967). The intensity of yellow colour was read spectrophotometrically in the spectronic - 20D at 420 nm and the phosphorus content in grain and straw samples was calculated and expressed as percentage.

3.5.4 Potassium and Sodium

Using an aliquot of triacid extract with suitable dilution, potassium and sodium were determined by using flame photometer and expressed as percentages.

3.5.5 Calcium and Magnesium

Calcium plus magnesium was determined by titrating the aliquot of the extract against standard versenate solution using EBT indicator. A separate estimation for calcium was made using versenate titration method with murexide indicator. Magnesium was calculated by the difference between these two (Jackson, 1967).

3.6 Estimation of soluble cations and anions in the soil samples from soil column leaching study

3.6.1 Extraction

Thirty grams of well ground soil was taken in a conical flask, to which 75 ml of distilled water was added and was shaken on a horizontal shaker for 30 minutes and the extract was collected.

3.7 Estimation of water soluble cations

3.7.1 Potassium and Sodium

Potassium and sodium in the soil water extract of 1:2.5 was estimated by using flame photometer (USSL Staff, 1954).

3.7.2 Calcium and magnesium

Calcium and magnesium were estimated by versenate titration (USSL Staff, 1954).

3.8 Water soluble anions

3.8.1 Carbonates and bicarbonates

Carbonates and bicarbonates in the extract were estimated immediately after extraction of soil by titrating against standard sulphuric acid using methyl orange and phenolphthalein indicators (USSL staff 1954).

3.8.2 Sulfate

Sulfate was estimated after precipitating sulphate as barium sulphate and turbidity developed was measured using systronics spectrophotometer (Black, 1965).

3.8.3 Chloride

Chloride was determined by titrating the extractant against standard silver nitrate using potassium dichromate as an indicator (USSL staff 1954).

3.9 Exchangeable cations

Exchangeable potassium, sodium, calcium and magnesium of the soil from soil column study were estimated as per the methods explained under the estimation of exchangeable cations of the soils from field experiment.

3.10 Statistical analysis

The data was statistically analysed following Fishers method of analysis of variance. Level of significance used in the 'F' and 't' test was $P = 0.05$.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the present investigation are presented in this chapter.

4.1 Yield of crops

4.1.1 Sugarcane

Yield of crops due to distillery effluent irrigation is shown in Table 2. The yield of sugarcane increased with decrease in effluent dilution. The highest cane yield of 110.87 t/ha was noticed in 1:10 effluent dilution. However, the yield was significantly higher in plots treated with different effluent dilution when compared to control (72.77 t/ha).

Yield of sugarcane due to amendments varied from 72.50 (control) to 93.78 t/ha (pressmud). The yield of cane under different amendments differed significantly with each other. The lowest cane yield was noticed in non-amended (control) soil.

Interactions between effluent river water ratio's and amendments were significant.

4.1.2 Maize (during rabi)

Maize crop yield was higher with effluent dilution irrigation. Highest grain yield (80.17 q/ha) was noticed in 1:10 effluent dilution which was significantly superior over

other dilutions and control. However, all other effluent dilutions recorded significantly higher yield when compared to control (69.23 q/ha). The yield of maize (69.23 q/ha) under river water, was on par with yield (70.28 q/ha) under 50 times effluent dilution irrigation.

Application of amendments significantly improved the grain yield of maize. The pressmud application recorded significantly higher grain yield when compared to other treatments. The yield of maize under control (68.11 q/ha) and gypsum were on par with each other.

Interactions between main and subtreatments were found to be nonsignificant.

4.1.3 Wheat

Wheat during rabi recorded higher grain yield (31.09 q/ha) under 1:50 effluent dilution which was on par with yield under river water irrigation and significantly superior over the yield recorded by 1:10 dilution.

Application of pressmud significantly increased the grain yield (32.43 q/ha) when compared to other amendments. Yield of wheat under non amended and gypsum treated plots were on par with each other.

Interaction effect of effluent dilution and amendments on yield of crops was non significant.

Table 2 : Yield of crops due to distillery effluent irrigation

Sugarcane (t/ha)					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	82.780	88.270	98.210	110.870	95.030
1:25	74.330	77.780	86.550	95.280	83.490
1:50	68.970	73.430	79.820	86.510	77.190
0:100	63.910	69.230	75.490	82.450	72.770
Mean	72.500	77.180	85.020	93.780	82.180
	S.Em±	C.D. at 5%			
A	0.915	4.119			
B	0.564	1.739			
A X B	1.128	3.478			
B X A	1.339	4.596			
Maize during Rabi (q/ha)					
1:10	74.710	77.080	81.660	87.240	80.170
1:25	67.870	69.670	74.700	79.720	72.990
1:50	65.410	67.740	70.600	77.360	70.280
0:100	64.430	66.250	70.190	76.070	69.230
Mean	68.110	70.180	74.290	80.100	73.170
	S.Em±	C.D. at 5%			
A	0.359	1.616			
B	0.817	2.518			
A X B	1.634	NS			
B X A	1.410	NS			
Wheat (q/ha)					
1:10	25.290	27.070	28.390	29.690	27.610
1:25	26.000	27.610	28.720	31.900	28.560
1:50	29.040	29.840	31.130	34.360	31.090
0:100	28.240	29.710	30.300	33.770	30.500
Mean	27.140	28.500	29.640	32.430	29.440
	S.Em±	C.D. at 5%			
A	0.356	1.604			
B	0.518	1.598			
A X B	1.037	NS			
B X A	0.966	NS			
A - Main treatment B - Sub treatment					
AXB, BXA-Interaction at same level of sub treatment and main treatment					

4.2 Straw Yield

The data on straw yield of maize and wheat crops are presented in Table 3.

4.2.1 Maize (grown in rabi)

The highest straw yield was recorded by maize grown in rabi under 1:10 effluent : river water dilution (84.51 q/ha) which was significantly higher than all other treatments. However, the Krishna river water irrigated crop recorded significantly lowest straw yield (76.58 q/ha).

Among the use of different amendments application of pressmud recorded significantly highest straw yield (85.07 q/ha). Straw yield of maize obtained under non amended and gypsum amended treatments were non significant. Straw yield due to interaction of effluent dilution ratio and amendments was non-significant.

4.2.2 Wheat

Wheat raised during rabi season recorded significantly highest straw yield under 1:10 effluent : river water dilution (51.42 q/ha). The straw yield of 43.01 q/ha under river water irrigation was the lowest of the effluent ratios tried.

Table 3 : Straw yield (Q/ha) of crops due to distillery effluent irrigation and amendments

----- Maize during Rabi -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	79.870	82.650	86.720	88.800	84.510
1:25	76.650	77.120	81.740	84.590	80.020
1:50	74.280	76.890	80.380	84.630	79.040
0:100	72.060	73.770	78.230	82.280	76.580
Mean	75.710	77.610	81.770	85.670	80.040

	S.Em±	C.D. at 5%			
A	0.317	1.425			
B	0.692	2.133			
A X B	1.384	NS			
B X A	1.240	NS			

Wheat					
1:10	47.250	48.890	53.060	56.490	51.420
1:25	44.810	46.670	48.490	51.780	47.940
1:50	42.780	44.570	45.830	47.100	45.240
0:100	41.560	42.660	44.360	45.860	43.610
Mean	44.100	45.700	47.940	50.300	47.050

	S.Em±	C.D. at 5%			
A	0.333	1.500			
B	0.475	1.464			
A X B	0.950	NS			
B X A	0.888	NS			

The application of pressmud as an amendment increased the straw yield (50.30 q/ha) significantly.

Interaction effect of effluent dilution and amendments on straw yield was found to be non significant.

4.3 Soil reaction

The data on the changes in pH of soil due to diluted distillery effluent irrigation after the harvest of crops are presented in Table 4.

The pH of soils collected after the harvest of sugarcane, maize during rabi and wheat varied significantly among themselves.

4.3.1 Sugarcane Plot

There was reduction in the soil pH values of effluent treated plots when compared to Krishna river treated plots (7.93). More reduction in pH value was observed in 10 times diluted effluent treated plots (7.65).

Reduction in pH of soil due to amendment was highest in case of pressmud over unamendment control plots in respect of amendment application.

There was no significant interaction effect between effluent dilutions and amendments.

Table 4 : Changes in pH of soils due to distillery effluent irrigation after the harvest of crops

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	7.775	7.660	7.620	7.565	7.655
1:25	7.990	7.915	7.785	7.690	7.845
1:50	8.000	7.945	7.830	7.710	7.871
0:100	8.060	7.950	7.895	7.805	7.928
Mean	7.956	7.868	7.783	7.693	7.825
	S.Em±	C.D. at 5%			
A	0.020	0.089			
B	0.011	0.034			
A X B	0.022	NS			
B X A	0.027	NS			
----- Maize followed by soybean (K) 1993-94 -----					
1:10	7.725	7.655	7.560	7.465	7.601
1:25	7.790	7.720	7.625	7.530	7.666
1:50	8.160	8.040	7.930	7.840	7.993
0:100	8.020	7.965	7.870	7.780	8.159
Mean	7.923	7.845	7.746	7.630	7.850
	S.Em±	C.D. at 5%			
A	0.124	0.558			
B	0.127	0.431			
A X B	0.254	NS			
B X A	0.253	NS			
----- Wheat followed by Maize (K) 1993-94 -----					
1:10	7.725	7.610	7.550	7.480	7.591
1:25	7.995	7.920	7.835	7.740	7.873
1:50	8.050	7.980	7.835	7.745	7.903
0:100	8.145	8.040	7.830	7.780	7.949
Mean	7.979	7.888	7.763	7.686	7.829
	S.Em±	C.D. at 5%			
A	0.023	0.103			
B	0.100	0.031			
A X B	0.020	0.062			
B X A	0.029	0.105			

4.3.2 Maize plots

In these soils also there was reduction in the pH values of effluent treated plots when compared to soils irrigated with Krishna river water (8.15).

Application of pressmud showed drastic decrease in pH values (7.63) when compared to other amendments. The pH under treatments 1:10, 1:25 and 1:50 were on par with each other.

No significant interaction was observed among the effluent dilution and amendments.

4.3.3 Wheat

Same trend of results were seen for wheat as observed for sugarcane and maize during rabi season. However interaction between effluent dilutions and amendments was significant. The reduction in pH values with the use of diluted effluent water is 0:100 > 1:50 > 1:25 > 1:10.

4.4 Electrical conductivity

4.4.1 Sugarcane plot

The data on EC of soils after the harvest of crops is presented in Table 5.

Application of effluent diluted with river water generally increased the EC of soils. There was significant increase in the EC of soils with the increase in the

concentration of effluent. The plots receiving 10 times diluted effluent recorded significantly higher EC values (0.82 dS m^{-1}) over other treatments.

Application of pressmud recorded higher EC values (0.80 dS m^{-1}) when compared to other amendments.

Interaction observed among effluent treatments and subtreatments was significant.

4.4.2 Maize plots

Maize (grown during rabi) soils which received lowest dilution of effluent (1:10) recorded highest EC (0.806 dS m^{-1}) values over other treatments.

Application of pressmud has caused rise in the EC value significantly.

No significant interaction effects were observed between effluent dilutions and subtreatments.

4.4.3 Wheat plots

The same effect as seen for maize (grown during rabi) plots was observed here also. Interaction effects were found non significant between effluent dilution and amendments.

Table 5 : Changes in EC (dSm-1) of soils due to distillery effluent irrigation after the harvest of crops

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	0.685	0.800	0.860	0.930	0.819
1:25	0.630	0.660	0.740	0.770	0.700
1:50	0.610	0.650	0.720	0.760	0.685
0:100	0.590	0.670	0.700	0.740	0.675
Mean	0.629	0.695	0.755	0.800	0.720

	S.Em±	C.D. at 5%			
A	0.003	0.015			
B	0.005	0.015			
A X B	0.010	0.031			
B X A	0.009	0.029			

Maize (R) followed by soybean (K) 1993-94					
1:10	0.685	0.765	0.825	0.950	0.806
1:25	0.590	0.630	0.670	0.750	0.660
1:50	0.560	0.620	0.660	0.730	0.643
0:100	0.540	0.600	0.660	0.720	0.630
Mean	0.594	0.654	0.704	0.788	0.685

	S.Em±	C.D. at 5%			
A	0.005	0.023			
B	0.008	0.025			
A X B	0.016	NS			
B X A	0.015	NS			

Wheat (R) followed by Maize (K) 1993-94					
1:10	0.645	0.675	0.735	0.795	0.713
1:25	0.560	0.585	0.650	0.715	0.628
1:50	0.550	0.590	0.635	0.675	0.613
0:100	0.530	0.575	0.625	0.660	0.597
Mean	0.571	0.606	0.661	0.711	0.638

	S.Em±	C.D. at 5%			
A	0.006	0.028			
B	0.006	0.020			
A X B	0.013	NS			
B X A	0.013	NS			

4.5 Organic carbon (OC)

The data on changes in organic carbon (%) status of soils due to diluted distillery effluent are presented in Table 6.

4.5.1 Sugarcane plot

Increase in the organic carbon (%) content of soil with the decrease in effluent concentration was noticed. Organic carbon content of soils in all the effluent treated plots differed significantly over control (0.60%). The plots receiving 1:10 diluted effluents recorded highest OC (0.75%) which was followed by 1:25 effluent dilution plots (0.68%).

Among the amendments tried, pressmud increased the OC which was significantly superior over other amendment treatments.

No significant interaction effects were observed among the effluent dilutions and amendments.

4.5.2 Wheat plot

All the effluent treated plots significantly increased the OC in soils when compared to control. The 1:10 dilution was significantly superior over other treatments (0.80%). The lowest OC was recorded by the control (0.57%).

Table 6 : Changes in organic carbon (%) of soils due to distillery effluent irrigation after the harvest of crops

Sugarcane					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	0.565	0.740	0.825	0.855	0.746
1:25	0.590	0.605	0.720	0.805	0.680
1:50	0.520	0.655	0.725	0.815	0.679
0:100	0.510	0.565	0.650	0.685	0.603
Mean	0.596	0.641	0.730	0.790	0.677
	S.Em±	C.D. at 5%			
A	0.009	0.039			
B	0.012	0.037			
A X B	0.024	NS			
B X A	0.023	NS			
Wheat followed by Maize (K) 1993-94					
1:10	0.705	0.795	0.845	0.870	0.804
1:25	0.645	0.690	0.725	0.870	0.732
1:50	0.620	0.705	0.705	0.720	0.688
0:100	0.495	0.570	0.595	0.620	0.570
Mean	0.616	0.690	0.718	0.770	0.698
	S.Em±	C.D. at 5%			
A	0.010	0.043			
B	0.032	0.098			
A X B	0.064	NS			
B X A	0.056	NS			
Maize followed by soybean (K) 1993-94					
1:10	0.640	0.670	0.825	0.830	0.741
1:25	0.605	0.655	0.690	0.745	0.674
1:50	0.530	0.600	0.690	0.750	0.643
0:100	0.520	0.570	0.590	0.610	0.573
Mean	0.574	0.624	0.699	0.734	0.658
	S.Em±	C.D. at 5%			
A	0.018	0.083			
B	0.014	0.044			
A X B	0.028	NS			
B X A	0.031	NS			

Application of pressmud improved the OC to a greater extent (0.77%) when compared to other amendments.

No significant interaction effects were observed between effluent dilutions and amendments.

4.5.3 Maize plots

The same trend of results were seen for maize plots as observed for sugarcane and wheat soils. Interaction effects were found to be nonsignificant.

4.6 Available Nitrogen

The data on available nitrogen of soils due to distillery effluent dilution are presented in Table 7.

4.6.1 Sugarcane plots

All the effluent diluted irrigation plots performed significantly superior over river water irrigated plots. Highest available nitrogen was recorded under 10 times effluent diluted plots (308.58 kg/ha). However all the effluent treated plots were on par with each other in respect of available nitrogen.

Use of pressmud found to increase the available nitrogen content of soil to a greater extent (325.31 kg/ha) when compared to other subtreatments. However, all the amendments tried plots recorded significantly higher values over non amended plots.

Interactions between effluent dilutions and amendment were found to be nonsignificant.

4.6.2 Maize (grown in rabi) plots

Here, also 1:10 effluent dilution plots recorded higher available nitrogen content (328.08 kg/ha) when compared to other treatments which was followed by 1:25 plots (323.50 kg/ha). The lowest available N was recorded under river water irrigated plots (290.90 kg/ha).

Application of pressmud also increased the available N content to a significantly higher level (336.17 kg/ha) when compared to other amendments.

No significant interaction effects were observed between effluent dilution and amendments.

4.6.3 Wheat plots

The available N content was highest (328.04 kg/ha) under 1:10 effluent : river water treated plots and was on par with available N content under 1:25 effluent dilution plots.

Pressmud application has given significantly superior available N (333.17 kg/ha) over other amendment treatments.

No significant interaction effects were noticed between main and subtreatments.

Table 7 : Changes in available nitrogen (kg/ha) of soils due to distillery effluent irrigation after the harvest of crops

Sugarcane					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	275.550	302.450	312.852	343.500	308.588
1:25	273.189	298.932	319.732	324.431	304.110
1:50	282.220	300.320	303.120	324.220	302.470
0:100	260.150	277.700	288.600	309.100	283.887
Mean	272.770	294.850	306.070	325.310	299.760
	S.Em±	C.D. at 5%			
A	3.826	17.327			
B	3.463	10.675			
A X B	6.927	NS			
B X A	7.115	NS			
Maize (R) followed by soybean (K) 1993-94					
1:10	313.000	325.250	335.500	349.700	328.083
1:25	306.000	318.800	325.500	343.700	323.500
1:50	283.050	297.200	315.350	337.300	308.225
0:100	272.350	286.000	291.250	314.000	290.900
Mean	293.600	306.988	316.900	336.175	312.677
	S.Em±	C.D. at 5%			
A	3.875	17.437			
B	2.940	10.290			
A X B	5.900	NS			
B X A	6.450	NS			
Wheat (R) followed by Maize (K) 1993-94					
1:10	310.000	322.950	332.500	348.700	328.038
1:25	303.000	315.800	322.500	340.700	320.500
1:50	280.050	294.200	312.350	334.300	305.225
0:100	269.350	283.000	288.250	311.000	287.900
Mean	290.600	303.988	313.900	333.175	310.416
	S.Em±	C.D. at 5%			
A	3.698	16.646			
B	2.937	9.053			
A X B	5.875	NS			
B X A	6.290	NS			

4.7 Available P_2O_5

The data on available P_2O_5 content of soils due to distillery effluent irrigation are presented in Table 8.

4.7.1 Sugarcane plots

There was significant increase in the Av P_2O_5 content of the soils irrigated with diluted effluent. The plots receiving 1:10 effluent dilution recorded highest available P_2O_5 content (29.80 kg/ha) and was significantly superior over control (23.75 kg/ha). However, the available P_2O_5 different ratios of effluent dilution remained on par with each other.

Among the amendments, available P_2O_5 was highest (33.50 kg/ha) under pressmud and differed significantly over rest of the treatments.

Difference in available P_2O_5 due to interactions, of effluent dilutions and amendment treatments were non significant.

4.7.2 Maize (in rabi) plots

The highest available P_2O_5 of soil (31.82 kg/ha) was recorded by 1:10 effluent dilution plots which was followed by 25 times effluent dilution plots. However all the effluent treated plots recorded significantly higher available P_2O_5 content over control (22.83 kg/ha).

Table 8 : Changes in available P_2O_5 (kg/ha) of soils due to distillery effluent irrigation after the harvest of crops

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	23.250	27.350	31.650	36.950	29.800
1:25	22.550	27.450	30.400	33.900	28.575
1:50	21.950	25.500	28.800	33.150	27.350
0:100	20.175	20.950	23.900	30.000	23.756
Mean	21.981	28.313	28.688	33.500	27.370

	S.Em±	C.D. at 5%			
A	0.558	2.512			
B	0.381	1.174			
A X B	0.761	NS			
B X A	0.864	NS			

Maize (R) followed by soybean (K) 1993-94					
1:10	24.900	29.950	35.075	37.375	31.825
1:25	22.550	26.600	30.200	34.950	28.575
1:50	20.925	25.300	26.650	31.350	26.056
0:100	19.400	21.480	24.450	26.000	22.833
Mean	21.944	25.833	29.094	32.410	27.322

	S.Em±	C.D. at 5%			
A	0.423	1.903			
B	0.408	1.259			
A X B	0.817	2.518			
B X A	0.824	2.678			

Wheat (R) followed by Maize (K) 1993-94					
1:10	23.200	28.650	33.225	38.500	30.890
1:25	22.350	25.600	29.650	37.200	28.700
1:50	19.600	25.500	28.100	32.900	26.525
0:100	19.850	22.150	25.100	26.750	23.463
Mean	21.250	25.475	29.019	33.838	27.395

	S.Em±	C.D. at 5%			
A	0.685	3.085			
B	0.304	0.938			
A X B	0.609	1.887			
B X A	0.865	3.141			

Available P_2O_5 content of soil (32.12 kg/ha) under pressmud application was significantly superior over rest of the subtreatments. The lowest available P_2O_5 of 21.34 kg/ha was observed under no amendment treatment. Significant interaction effect were noticed between effluent dilutions and amendments.

4.7.3 Wheat plots

Same trend of results were seen for wheat plots as observed in sugarcane and maize plots in respect of available P_2O_5 .

Interaction effects between effluent dilutions and amendments were significant in respect of available P_2O_5 content of soil.

4.8 Available K_2O

Changes in available K_2O (kg/ha) due to effluent dilutions and amendments are presented in Table 9.

4.8.1 Sugarcane plots

There was significant increase in the content available K_2O with the application of diluted distillery effluent water. The highest available K_2O was recorded by 1:10 effluent diluted plots (539.29 kg/ha) and was on par with available K_2O (525.3 kg/ha) under 1:25 effluent dilution. All

the effluent treated plots registered significantly higher available K_2O value over control (389.42 kg/ha). Available K_2O content under amendment treatments differed significantly with each other.

Interaction effects noticed between effluent dilutions and amendments were significant.

4.8.2 Maize (in rabi) soils

The highest available K_2O content was recorded in soils under effluent dilution of 1:10 (495.16 kg/ha) which was significantly superior over control (430.35 kg/ha). The Av K_2O of 10 times diluted effluent plots were on par with available K_2O content under 1:25 effluent dilution. Available K_2O content of soils under all the effluent treated plots was higher compared to control.

Application of pressmud significantly increased the available K_2O (507.51 kg/ha) content of soil. All the amendment treated soils contained significantly superior over unamended control soil (428.67 kg/ha). Available K_2O content under different amendments in the decreasing order was : pressmud (507.51 kg/ha) > pressmud + Gypsum (484.29 kg/ha) > Gypsum (451.07 kg/ha) > Control (428.67 kg/ha).

Interaction effects observed between main and subtreatments in respect of available K_2O were significant.

Table 9 : Changes in available K_2O (kg/ha) of soils due to distillery effluent irrigation after the harvest of crops

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	483.650	511.250	566.100	596.150	539.288
1:25	446.800	498.900	571.350	584.200	525.313
1:50	417.600	450.550	526.800	566.800	490.438
0:100	373.350	353.850	409.100	421.400	389.425
Mean	430.350	453.638	518.338	542.138	486.116

	S.Em±	C.D. at 5%			
A	5.863	26.390			
B	5.368	16.544			
A X B	10.735	33.089			
B X A	10.991	35.902			

Maize (R) followed by soybean (K) 1993-94					
1:10	448.050	467.300	514.500	550.800	495.163
1:25	444.750	466.700	505.950	529.900	486.825
1:50	422.300	437.700	479.400	797.450	459.213
0:100	399.600	432.600	437.300	451.900	430.350
Mean	428.675	451.075	484.288	507.513	467.888

	S.Em±	C.D. at 5%			
A	7.908	35.596			
B	3.585	11.048			
A X B	7.169	22.097			
B X A	10.054	36.386			

Wheat (R) followed by Maize (K) 1993-94					
1:10	450.850	485.250	525.800	563.600	506.375
1:25	442.650	458.950	519.400	542.250	490.813
1:50	435.550	450.350	457.350	482.450	456.425
0:100	345.800	372.100	406.350	432.500	389.188
Mean	418.712	441.663	477.225	505.200	460.700

	S.Em±	C.D. at 5%			
A	5.254	23.649			
B	4.298	13.248			
A X B	8.596	26.495			
B X A	9.112	30.119			

4.8.3 Wheat soil

Same trend of results of available K_2O of soil as observed in case of soils under maize were obtained for wheat soil also.

Interaction effects were found significant between main and sub treatments.

4.9 Exchangeable calcium

The data on exchangeable calcium of soil after the harvest of crops are given in Table 10.

4.9.1 Sugarcane plots

Exchangeable calcium content of the soil increased with the use of effluent irrigation. Highest exchangeable calcium content was recorded by 1 : 10 dilution plots ($37.31 \text{ cmol}(p^+) \text{ kg}^{-1}$) and was significantly superior over other effluent dilution treatments and control. The control plot soils found to contain the lowest exchangeable calcium ($30.21 \text{ cmol}(p^+) \text{ kg}^{-1}$).

Among the amendments pressmud plus gypsum applied plots resulted significantly higher exchangeable calcium content ($40.25 \text{ cmol}(p^+) \text{ kg}^{-1}$) which was followed by pressmud ($34.59 \text{ cmol}(p^+) \text{ kg}^{-1}$).

Differences in exchangeable calcium of soil due to interaction of effluent dilution and amendments were significant.

4.9.2 Maize (in rabi) soils

Use of effluent and Krishna river water in 1:10 dilution recorded highest exchangeable calcium content ($41.74 \text{ cmol(p}^+\text{)kg}^{-1}$). This was closely followed by 1:25 dilution. However all the effluent treated plots remained on par with each other. The control recorded the lowest exchangeable calcium content ($37.10 \text{ cmol(p}^+\text{)kg}^{-1}$). Application of amendments significantly improved the exchangeable calcium content. The highest and lowest exchangeable calcium in soils were observed for gypsum plus pressmud and non amended treatments respectively.

Significant interaction effects were observed between main and subtreatments.

4.9.3 Wheat soils

The highest exchangeable calcium content was recorded by 1:10 effluent dilution which was on par with 1:25 and 1:50 effluent dilution. However, all the effluent treated plots found to contain significantly higher exchangeable calcium over control ($32.41 \text{ cmol(p}^+\text{)kg}^{-1}$).

Table 10 : Changes in exchangeable calcium [C mol (P+)kg-1]
of soils due to distillery effluent irrigation
after the harvest of crops

Sugarcane					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	28.900	35.900	45.000	39.450	37.313
1:25	24.600	32.500	42.500	35.000	33.650
1:50	25.000	29.750	36.500	33.300	31.138
0:100	26.500	26.750	37.000	30.600	30.213
Mean	26.250	31.225	40.250	34.588	33.078
	S.Em±	C.D. at 5%			
A	0.424	1.911			
B	0.312	0.961			
A X B	0.623	1.921			
B X A	0.687	2.300			
Maize (R) followed by soybean (K) 1993-94					
1:10	32.000	38.500	50.000	46.450	41.737
1:25	31.000	37.500	49.000	45.450	40.738
1:50	33.062	37.632	47.112	43.820	40.349
0:100	31.600	32.550	46.500	37.750	37.100
Mean	31.910	36.478	48.153	43.378	39.981
	S.Em±	C.D. at 5%			
A	0.690	3.105			
B	0.686	2.113			
A X B	1.371	4.154			
B X A	1.364	5.728			
Wheat (R) followed by Maize (K) 1993-94					
1:10	33.750	38.500	47.000	44.600	40.963
1:25	29.250	36.050	45.250	42.250	38.200
1:50	24.750	35.250	46.250	44.250	37.625
0:100	27.500	29.650	37.000	35.203	32.413
Mean	28.813	34.863	43.950	41.575	37.300
	S.Em±	C.D. at 5%			
A	0.716	3.224			
B	0.126	0.387			
A X B	0.251	0.775			
B X A	0.749	3.160			

Same trend of results were observed with respect to subtreatments as noticed for above two soils. Significant interaction effects were also noticed.

4.10 Exchangeable magnesium

The data on exchangeable magnesium are furnished in Table 11.

4.10.1 Sugarcane soils

There was ex. Mg with the increase in effluent concentration in irrigation water. Highest exchangeable magnesium was recorded by only Krishna river water irrigation. All the effluent treated plots showed significantly lower exchangeable magnesium content over control ($31.48 \text{ cmol(p}^+\text{)kg}^{-1}$).

Among the amendments, application of pressmud increased the exchangeable magnesium content to a significantly higher level ($31.38 \text{ cmol(p}^+\text{)kg}^{-1}$) when compared to other amendment treatments.

No significant interaction effects were noticed between main and subtreatments.

4.10.2 Maize (in rabi) soils

Use of Krishna river water (control) alone significantly improved the exchangeable magnesium content

Table 11 : Changes in exchangeable magnesium [C mol (P+)kg⁻¹] of soils due to distillery effluent irrigation after the harvest of crops

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	18.700	21.900	25.000	29.350	23.738
1:25	25.900	27.350	34.250	38.400	31.475
1:50	23.250	33.500	37.000	38.400	33.037
0:100	24.150	31.900	36.850	42.050	33.738
Mean	23.000	28.663	33.275	37.050	30.497

	S.Em±	C.D. at 5%			
A	0.293	1.320			
B	0.725	2.236			
A X B	1.451	NS			
B X A	1.290	NS			

Maize (R) followed by soybean (K) 1993-94					
1:10	19.050	21.850	21.600	26.000	22.125
1:25	18.000	23.150	26.400	28.950	24.125
1:50	19.250	24.200	28.350	31.400	25.875
0:100	21.100	25.750	31.950	35.450	28.563
Mean	19.350	23.738	27.150	30.450	25.172

	S.Em±	C.D. at 5%			
A	0.504	2.269			
B	0.416	1.283			
A X B	0.832	2.565			
B X A	0.880	2.905			

Wheat					
1:10	18.600	19.500	23.700	27.500	21.825
1:25	21.950	23.200	25.500	32.400	25.775
1:50	22.100	25.900	26.950	30.100	26.263
0:100	24.500	30.450	33.450	37.550	31.488
Mean	21.788	24.763	27.412	31.388	26.338

	S.Em±	C.D. at 5%			
A	0.263	1.183			
B	0.381	1.173			
A X B	0.761	3.347			
B X A	0.710	2.244			

(28.56 cmol(p⁺)kg⁻¹) over diluted effluent treated plots. All the effluent treated plots recorded lower exchangeable magnesium.

Use of pressmud significantly increased the exchangeable magnesium content over control.

Significant interaction effects were noticed between main and subtreatments.

4.10.3 Wheat soils

Same trend of results were observed for wheat soils as mentioned for above two soils.

Significant interaction effects were noticed between main and subtreatments.

4.11 Exchangeable sodium

The results of exchangeable sodium of soil after the harvest of crops are given in Table 12.

4.11.1 Sugarcane soils

There was reduction in the exchangeable Na with the decrease in effluent dilution. Exchangeable sodium of soil irrigated with river water was the highest and it was on par with exchangeable Na under 50 times effluent dilution. The lowest exchangeable Na (1.39 cmol(p⁺)kg⁻¹) noticed under 10

times effluent dilution was significantly differed from rest of the treatment.

The highest reduction in exchangeable Na of soil ($1.42 \text{ cmol(p}^+\text{)kg}^{-1}$) was recorded under press mud plus gypsum and it differed significantly with rest of the treatments. Next highest reduction in exchangeable Na ($1.67 \text{ cmol(p}^+\text{)kg}^{-1}$) was noticed under gypsum followed by pressmud ($1.90 \text{ cmol(p}^+\text{)kg}^{-1}$).

Interaction of effluent dilutions and amendments were significant in respect of exchangeable Na content.

4.11.2 Maize (in rabi) soil

Reduction in the exchangeable Na content of the soil was noticed in 1:10 effluent dilution treatment ($1.60 \text{ cmol(p}^+\text{)kg}^{-1}$). However difference in the exchangeable Na content of soil due to effluent dilution ratio was non significant.

Application of amendments significantly reduced the exchangeable Na content as compared to control. Highest reduction of exchangeable Na compared to non amended soil was observed in gypsum plus pressmud treatment which differed significantly with rest of the treatments.

Significant interaction effects were observed between main and subtreatments.

Table 12: Changes in exchangeable sodium [C mol (P+)kg-1] of soils due to distillery effluent irrigation after the harvest of crops

Sugarcane					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	1.905	1.275	0.985	1.400	1.391
1:25	2.040	1.590	1.405	1.810	1.711
1:50	2.100	1.970	1.790	2.085	1.986
0:100	2.440	1.860	1.490	2.305	2.024
Mean	2.121	1.674	1.418	1.900	1.778
	S.Em±	C.D. at 5%			
A	0.067	0.301			
B	0.032	0.098			
A X B	0.064	0.196			
B X A	0.087	0.311			
Maize (R) followed by soybean (K) 1993-94					
1:10	2.405	1.470	1.165	1.380	1.605
1:25	2.455	1.520	1.215	1.430	1.655
1:50	2.430	1.480	1.320	1.565	1.698
0:100	2.335	1.975	1.625	2.050	1.996
Mean	2.406	1.611	1.331	1.606	1.738
	S.Em±	C.D. at 5%			
A	0.060	0.270			
B	0.034	0.106			
A X B	0.069	0.213			
B X A	0.084	0.293			
Wheat (R) followed by Maize (K) 1993-94					
1:10	2.430	1.885	1.500	2.170	1.996
1:25	2.630	1.735	1.625	2.140	2.033
1:50	2.575	1.945	1.895	2.090	2.126
0:100	2.880	2.450	2.210	2.540	2.520
Mean	2.629	2.004	1.808	2.235	2.169
	S.Em±	C.D. at 5%			
A	0.032	0.144			
B	0.038	0.166			
A X B	0.075	NS			
B X A	0.073	NS			

4.11.3 Wheat soils

Same trend of results were obtained for wheat soils as observed for above mentioned soils.

However the interaction effects between main and subtreatments were found to be non significant.

4.12 Plant composition at harvest

4.12.1 Nitrogen uptake

The data on uptake of N by crops under different dilutions of effluents and amendments are furnished in Table 13.

4.12.1.1 Sugarcane

The total N uptake differed significantly with the use of diluted effluent irrigation. Highest total N uptake was seen in 1:10 effluent : Krishna river water dilution (133.06 kg/ha) which was followed by 1:25 plots (116.91 kg/ha). The control recorded the least total N uptake (101.88 kg/ha).

Application of pressmud significantly improved the N uptake (130.04 kg/ha). All the amendment applied plots significantly improved the plant N uptake compared to non amended plots.

Significant interaction effects were seen between main and subtreatments.

4.12.1.2 Wheat (rabi)

There was significant increase in plant N uptake with the use of effluent water. The highest plant N uptake was recorded by 1:10 effluent : river water plots (80.00 kg/ha) and was significantly higher than other effluent treated plots.

There was significant increase in plant N uptake (84.71 kg/ha) with pressmud application. The control recorded significantly lowest plant N uptake (65.32 kg/ha).

No significant interaction effects were observed between main and subtreatments.

4.12.1.3 Maize (rabi)

Highest plant N uptake was observed under 1:10 effluent : river water treatment (102.49 kg/ha) and was significantly higher than other treatments. However, all the effluent mixed river water treated plots recorded significantly higher plant N uptake over control.

Same trend of results were obtained with the application of amendments as observed for sugarcane.

Interaction effects noticed between main and subtreatments were significant in respect of nitrogen uptake by maize.

Table 13 : Uptake of total nitrogen (kg/ha) by crops under different dilutions of distillery effluent

Sugarcane					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	115.930	123.580	137.495	155.215	133.060
1:25	104.065	109.035	121.170	133.390	116.915
1:50	96.560	102.805	111.750	116.115	106.808
0:100	89.475	96.915	105.690	115.435	101.879
Mean	101.513	108.084	119.026	130.039	114.665
	S.Em±	C.D. at 5%			
A	1.525	6.864			
B	0.988	3.044			
A X B	1.975	6.089			
B X A	2.292	7.810			
Wheat (R)					
1:10	70.550	77.625	80.870	90.980	80.006
1:25	65.090	68.335	76.340	85.375	73.785
1:50	63.420	71.610	72.205	80.625	71.825
0:100	62.220	69.845	70.320	81.825	71.063
Mean	65.320	71.704	74.934	84.711	74.167
	S.Em±	C.D. at 5%			
A	1.009	4.543			
B	1.688	5.201			
A X B	3.375	NS			
B X A	3.092	NS			
Maize (R)					
1:10	96.120	100.310	105.220	108.310	102.490
1:25	88.860	90.220	93.860	102.660	93.900
1:50	88.560	90.790	94.010	95.460	92.200
0:100	81.540	86.360	88.290	96.760	88.230
Mean	88.770	91.920	95.340	100.790	94.200
	S.Em±	C.D. at 5%			
A	0.130	0.586			
B	0.124	0.381			
A X B	0.247	0.762			
B X A	0.251	0.816			

4.12.2 Phosphorus

The data on total P uptake are given in Table 14.

4.12.2.1 Sugarcane

Sugarcane crop under 10 times effluent dilution recorded significantly higher P uptake (23.75 kg/ha) when compared to other treatments. All the effluent treated sugarcane crop varied significantly over control in respect of uptake of phosphorous.

Among different amendments application, pressmud application recorded significantly higher plant P uptake over other treatments. Control recorded significantly lowest P uptake (18.12 kg/ha).

There was significant difference amongst interactions of effluent dilutions and amendments.

4.12.2.2 Maize (grown in rabi)

Significantly higher P uptake was recorded by maize crop under 1:10 effluent dilution (22.45 kg/ha). All the effluent treated plots showed significantly higher uptake of P when compared to control (18.19 kg/ha). However the uptake of P under effluent dilutions of 1:25 and 1:50 remained on par with each other.

Table 14 : Uptake of phosphorus (kg/ha) by crops under different dilutions of distillery effluent

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	20.690	22.065	24.550	27.710	23.754
1:25	18.580	19.465	21.635	23.815	20.874
1:50	17.240	18.355	19.955	21.625	19.294
0:100	15.975	17.300	18.870	20.610	18.189
Mean	18.121	19.296	21.253	23.440	20.528

	S.Em±	C.D. at 5%			
A	0.230	1.035			
B	0.140	0.431			
A X B	0.280	0.865			
B X A	0.334	1.149			

Maize (R)					
1:10	20.200	22.300	22.690	24.600	22.448
1:25	17.670	20.860	23.400	24.500	21.608
1:50	19.750	21.050	21.525	23.550	21.469
0:100	15.050	16.150	17.300	19.000	16.875
Mean	18.168	20.090	21.229	22.912	20.600

	S.Em±	C.D. at 5%			
A	0.097	0.434			
B	0.176	0.543			
A X B	0.353	1.087			
B X A	0.320	1.003			

Wheat (R)					
1:10	18.280	19.070	19.350	22.700	19.850
1:25	17.390	16.390	17.620	17.490	17.220
1:50	13.500	12.370	15.400	14.170	13.860
0:100	10.310	11.930	12.510	11.780	11.630
Mean	14.870	14.940	16.220	16.530	15.640

	S.Em±	C.D. at 5%			
A	0.337	1.514			
B	0.460	NS			
A X B	0.921	NS			
B X A	0.866	NS			

Application of pressmud significantly improved the plant P uptake which was followed by gypsum plus pressmud treatments. The control recorded significantly lower P uptake (18.17 kg/ha).

Significant interaction effects were seen between main and subtreatments.

4.12.2.3 Wheat (rabi)

Rabi wheat recorded significantly higher uptake of P under 1:10 effluent dilution (19.85 kg/ha) which was closely followed by 1:25 effluent dilution (17.22 kg/ha). However all the effluent treated plants were significantly superior over control.

Application of amendments remained on par with each other.

No significant interaction effects were noticed between effluent dilutions and amendments.

4.12.3 Potassium

The data on uptake of K by crops are perused in Table 15.

4.12.3.1 Sugarcane

There was significant increase in the uptake of

potassium under 1:10 effluent dilution (179.61 kg/ha). All the effluent treated plots recorded significantly higher uptake of potassium when compared to control (137.52 kg/ha). Reduction in uptake of K with the higher dilution of effluent was observed.

Application of pressmud (177.22 kg/ha) followed by gypsum plus pressmud (160.69 kg/ha) recorded significantly higher uptake of K. But uptake of K by sugarcane under different amendments differed significantly with each other. The lowest uptake of K was recorded by non amended control (137.02 kg/ha).

4.12.3.2 Maize (in rabi)

Maize crop showed significant increase in the uptake of potassium under 1:10 effluent dilution (91.62 kg/ha). However uptake of K under all other effluent dilution treatments observed to be significantly higher when compared to control (80.26 kg/ha). The treatments 1:25 and 1:50 effluent dilution remained on par with each other.

Uptake of K under amendments was significantly superior over the unamended control. Application of pressmud recorded highest uptake of K (93.21 kg/ha) amongst the amendments added.

Difference in the uptake of K due to interaction of effluent ratio's and amendments were on par with each other.

Table 15 : Uptake of potassium (kg/ha) by crops under different dilutions of distillery effluent

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	156.450	166.835	185.620	209.540	179.611
1:25	140.490	147.195	193.585	180.075	157.836
1:50	130.360	138.785	150.865	163.505	145.879
0:100	120.795	130.840	142.680	155.755	137.518
Mean	137.024	145.914	160.688	177.219	155.211

	S.Em±	C.D. at 5%			
A	1.745	7.853			
B	1.061	3.271			
A X B	2.123	6.542			
B X A	2.534	8.720			

Maize (R)					
1:10	84.100	89.700	93.850	98.850	91.625
1:25	81.100	84.750	89.000	92.400	86.813
1:50	82.550	85.575	95.550	93.830	88.626
0:100	73.600	76.950	82.750	87.750	80.263
Mean	80.338	84.244	89.538	93.208	86.832

	S.Em±	C.D. at 5%			
A	0.441	1.986			
B	0.622	1.917			
A X B	1.244	NS			
B X A	1.164	NS			

Wheat (R)					
1:10	64.360	66.570	72.470	74.370	69.440
1:25	54.970	57.660	59.930	63.450	59.000
1:50	46.270	56.260	54.220	58.380	53.780
0:100	45.560	47.300	49.650	52.510	48.750
Mean	52.790	56.940	59.060	62.170	57.740

	S.Em±	C.D. at 5%			
A	0.415	1.868			
B	0.751	2.315			
A X B	1.502	NS			
B X A	1.365	NS			

4.12.3.3 Wheat (rabi)

Wheat crop showed significantly higher uptake of potassium under 1:10 effluent dilution (69.44 kg/ha) which was followed by 1:25 and 1:50 effluent dilution. The control recorded significantly lowest uptake of K (48.75 kg/ha) when compared to effluent treated plots.

Application of pressmud showed significantly higher the uptake of K (62.17 kg/ha) when compared to other treatments and control. The uptake of K by wheat crop under different dilution treatments differed significantly with each other.

No significant interaction effects were observed.

4.12.4 Calcium

The data on uptake of Ca by crops due to effluent dilutions and amendments are perused in Table 16.

4.12.4.1 Sugarcane

The sugarcane crop was found to record significantly higher uptake of calcium when irrigated with different ratios of effluent : Krishna river water. Uptake of Ca by sugarcane crop (166.13 kg/ha) was highest under 1:10 times effluent dilution. But it was on par with the uptake of Ca under 1:25 effluent dilution.

Application of pressmud significantly increased the uptake of calcium (171.10 kg/ha). The control recorded significantly lowest calcium uptake (132.17 kg/ha).

Interaction effects on uptake of Ca observed between main and subtreatments remained nonsignificant.

4.12.4.2 Maize (During rabi)

The uptake of Ca by maize under 1:10 effluent dilution was highest (220.47 kg/ha) but it was on par with Ca uptake under 1:25 effluent dilution. The crops irrigated with only river water recorded significantly lowest uptake of Ca (171.76 kg/ha) which remained on par with 1:50 effluent dilution.

The increase in uptake of calcium (222.62 kg/ha) under pressmud as an amendment was significantly higher as compared to other effluent dilution treatments and control. However all the amendments treated plots remained significantly different with each other in respect of uptake of Ca.

No significant interaction effects were observed.

4.12.4.3 Wheat (rabi)

Wheat crop showed significantly higher uptake of Ca (57.66 kg/ha) under 1:10 effluent dilution. However all the effluent treated plots remained significantly superior over

Table 16 : Uptake of calcium (kg/ha) by crops under different dilutions of distillery effluent

Sugarcane					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	144.250	162.600	173.900	183.790	166.135
1:25	133.900	152.050	167.150	173.800	156.725
1:50	131.200	141.400	158.650	166.475	149.431
0:100	119.350	134.275	148.975	160.325	140.731
Mean	132.175	147.581	162.169	171.098	153.256
	S.Em±	C.D. at 5%			
A	2.309	10.392			
B	1.195	3.685			
A X B	2.391	NS			
B X A	3.101	NS			
Maize (R)					
1:10	177.150	195.400	204.275	230.200	201.756
1:25	170.600	185.450	196.200	214.650	191.725
1:50	170.600	185.450	196.200	214.650	191.725
0:100	145.700	168.100	177.800	195.450	171.763
Mean	170.750	191.713	200.638	222.619	196.430
	S.Em±	C.D. at 5%			
A	5.859	26.370			
B	1.078	3.324			
A X B	2.157	NS			
B X A	6.149	NS			
Wheat (R)					
1:10	52.580	55.680	57.840	64.570	57.660
1:25	48.670	49.570	53.750	55.870	51.960
1:50	45.100	45.600	47.410	49.740	46.960
0:100	37.970	42.570	42.620	46.380	42.380
Mean	46.080	48.350	50.400	54.140	49.740
	S.Em±	C.D. at 5%			
A	0.394	1.776			
B	0.471	1.450			
A X B	0.941	NS			
B X A	0.905	NS			

control. Effluent dilution treatments also differed significantly with each other in respect of calcium uptake by wheat crop.

Pressmud application significantly improved the uptake of Ca (54.14 kg/ha).

Interaction effects of effluent dilutions and amendments were non significant.

4.12.5 Magnesium

The data on uptake of Mg under different effluent dilutions and amendments are given in Table 17.

4.12.5.1 Sugarcane

Sugarcane crop recorded significantly higher uptake of magnesium (66.13 kg/ha) under 10 times effluent dilution when compared to 1:50 effluent dilution and control. However, uptake of Mg under 1:25, 1:50 dilutions and control remained on par with each other.

Application of pressmud significantly improved the crop uptake of Mg (70.62 kg/ha). All the amendment treated plots recorded significantly higher uptake of Mg when compared to control.

Uptake of Mg by sugarcane crop was non significant due to interactions of effluent dilutions and amendments.

4.12.5.2 Maize (During rabi)

Highest uptake of Mg by maize crop was recorded by 1:10 effluent dilution (99.71 kg/ha). All the effluent treated plots recorded significantly higher uptake of Mg when compared to control.

Application of pressmud was also found to take up significantly higher Mg (101.82 kg/ha). But the uptake of Mg due to amendments differed significantly.

No significant interaction effects were noticed between main and subtreatments.

4.12.5.3 Wheat (rabi)

Wheat crop recorded significantly higher uptake of Mg under 1:10 effluent dilution (33.21 kg/ha). The control recorded significantly lowest uptake of Mg (22.73 kg/ha) when compared to effluent treated plots. Amongst the effluent dilution treatments, there was significant difference with each other.

Application of pressmud recorded significantly highest uptake of Mg over other amendment treated plots and control.

No significant interaction effects were noticed between main and subtreatments.

Table 17 : Uptake of magnesium (kg/ha) by crops under different dilutions of distillery effluent

----- Sugarcane -----					
Effluent dilution (E.K.)	Subtreatments				
	C	G	G+P	P	Mean
1:10	44.250	62.600	73.900	83.790	66.135
1:25	33.900	52.050	67.150	73.800	56.725
1:50	31.200	41.400	58.650	66.475	49.431
0:100	27.700	35.600	49.150	58.400	42.713
Mean	34.263	47.913	62.212	70.616	53.751
	S.Em±	C.D. at 5%			
A	2.159	9.719			
B	1.047	3.227			
A X B	2.094	NS			
B X A	2.820	NS			

Maize (R)					
1:10	84.800	94.450	103.950	115.650	99.713
1:25	74.800	84.450	93.950	105.650	89.713
1:50	84.800	94.450	103.950	115.650	99.713
0:100	64.775	71.050	77.425	88.950	75.550
Mean	73.919	82.725	90.825	101.825	87.323
	S.Em±	C.D. at 5%			
A	1.063	4.787			
B	1.381	4.256			
A X B	2.761	NS			
B X A	2.617	NS			

Wheat (R)					
1:10	30.390	31.790	34.000	36.680	33.210
1:25	28.020	28.180	28.710	31.120	29.130
1:50	24.580	24.830	25.620	26.070	25.300
0:100	21.520	22.450	22.760	24.200	22.730
Mean	26.120	26.960	27.770	29.510	27.590
	S.Em±	C.D. at 5%			
A	0.141	0.635			
B	0.075	0.232			
A X B	0.150	NS			
B X A	0.192	NS			

4.13 Soil column studies

The data on pH, EC, exchangeable cations, and soluble cations and anions as affected by leaching of soil column with different ratio's of effluent : Krishna river water and amendments are presented in the tables from 19 to 30.

4.13.1

The data on pH of the soil column study are presented in Table 18. The pH of soil column leached with different levels of diluted lagoon spentwash showed significant differences not only in depth, dilution ratio's but also in their interactions.

The pH of the soil increased with depth. The lowest mean pH (7.93) was recorded at D1 depth followed by D2 and D3 depths. The lowest pH as affected by effluent dilution was observed in I₁ effluent dilution (7.86) which was significantly lower than 1:50 and 0:100 dilution levels. However, the pH of I₁ and I₂ were on par with each other. The pH due to amendments ranged from 8.01 (P) to 7.739 (G+P) and change in pH was not significant.

Interaction effects were found nonsignificant between IXD, AXD, IXAXD. However interaction effect between AXB was significant.

Table 18 : pH of the soil due to soil column leaching with diluted distillery effluent and amendments

	D ₁				D ₂				D ₃				I							
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
C	7.775	7.975	8.105	8.225	8.013	7.825	8.075	8.135	8.345	8.095	8.025	8.115	8.225	8.475	8.210	7.738	8.178	8.062	8.042	8.005
G	7.755	7.927	8.035	8.185	7.970	7.785	8.015	8.055	8.275	8.032	7.965	8.035	8.125	8.345	8.717	7.862	7.885	8.185	8.095	8.007
G+P	7.685	7.825	7.945	8.125	7.895	7.755	7.895	7.995	8.185	7.957	7.885	7.975	8.075	8.275	8.052	7.898	7.855	8.112	8.522	8.697
P	7.685	7.765	7.885	8.045	7.845	7.735	7.825	7.935	8.125	7.905	7.755	7.935	9.015	8.175	8.220	7.955	7.912	7.868	8.255	7.998
Mean	7.700	7.872	7.990	8.145	7.930	7.775	7.952	8.020	8.232	7.997	7.910	8.015	8.360	8.317	8.149	7.863	7.958	8.057	8.228	
S.E.m± C.D.at 5%																				
A		0.040	0.118																	
B		0.041	NS																	
C		0.036	NS																	
A X B		0.083	0.236																	
A X C		0.072	NS																	
B X C		0.072	NS																	
A X B X C		0.144	NS																	

4.13.2

The data on EC of soil are presented in Table 19. Incase of electrical conductivity significant differences were noticed among the depths, dilutions, amendments and interactions.

The electrical conductivity of soil increased numerically with depth having the highest EC (0.65 dSm^{-1}) for D_3 depth. The lowest (0.60 dSm^{-1}) and highest (0.63 dSm^{-1}) EC obtained was under I_4 and I_1 dilutions respectively. Application of amendments increased the mean EC values from 0.59 dSm^{-1} (C) to 0.65 dSm^{-1} (P).

The interaction effects between IXA, IXD, AXD and IXAXD were found to be significant. However the interaction was found non significant for C level.

4.13.3

The data on exchangeable sodium are given in Table 20. The change in exchangeable sodium content of soil column treated with different amendments and leached with various dilution ratio's of effluent with river water showed significant differences among depths, the dilutions, amendments and their interactions.

The significant increase in exchangeable sodium content with depth was observed. The lowest (2.38 Cmol

Table 19 : Electrical conductivity (dSml) content of the soil due to soil column leaching with diluted distillery effluent and amendments

	D ₁					D ₂					D ₃					I				
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
C	0.710	0.550	0.390	0.390	0.525	0.750	0.590	0.510	0.280	0.573	0.810	0.650	0.570	0.330	0.637	0.753	0.312	0.550	0.707	0.587
G	0.750	0.610	0.460	0.460	0.685	0.770	0.660	0.550	0.340	0.537	0.850	0.700	0.620	0.390	0.589	0.670	0.373	0.420	0.667	0.607
G+P	0.800	0.660	0.510	0.510	0.643	0.810	0.710	0.590	0.450	0.698	0.900	0.770	0.650	0.490	0.539	0.583	0.780	0.583	0.567	0.628
P	0.850	0.700	0.570	0.570	0.590	0.888	0.740	0.640	0.490	0.653	0.930	0.810	0.720	0.550	0.699	0.513	0.723	0.893	0.477	0.510
Mean	0.670	0.535	0.612	0.612	0.611	0.628	0.658	0.555	0.620	0.615	0.593	0.618	0.668	0.568	0.616	0.630	0.623	0.612	0.604	
S.E.m _t C.D.at 5%																				
A		0.003	0.012																	
B		0.002	0.010																	
C		0.002	NS																	
A X B		0.005	0.021																	
A X C		0.005	0.018																	
B X C		0.004	0.016																	
A X B X C		0.009	0.036																	

Table 20 : Exchangeable sodium (C mol (P+) kg-1) content of the soil due to soil column leaching with dilated distillery effluent and amendments

	D ₁					D ₂					D ₃					I				
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
C	1.770	1.900	2.100	2.360	2.040	2.300	2.420	2.600	2.900	2.459	3.100	3.920	4.150	5.170	3.173	1.752	2.336	2.454	3.659	2.570
G	1.680	1.700	1.980	2.300	1.805	1.950	2.050	2.255	2.600	2.813	2.800	3.600	3.850	4.600	2.525	1.615	1.838	2.681	3.641	2.444
GP	1.450	1.460	1.650	1.990	1.630	1.650	1.850	2.150	2.500	1.912	2.350	3.100	3.300	4.050	3.197	1.679	1.835	2.369	3.902	2.446
P	1.220	1.290	1.400	1.800	1.420	1.450	1.600	1.850	2.450	1.837	1.950	2.350	2.460	3.050	1.950	1.607	2.017	2.450	3.450	2.381
Mean	1.608	1.965	2.438	3.543	2.388	1.630	1.975	2.489	3.565	2.415	1.663	1.990	2.450	3.793	2.474	1.663	2.006	2.488	3.663	
S.E.m± C.D.at 5%																				
A		0.025	0.072																	
B		0.025	0.075																	
C		0.022	0.062																	
A X B		0.051	0.144																	
A X C		0.044	NS																	
B X C		0.044	0.125																	
A X B X C		0.088	0.249																	

(p+) kg⁻¹ being observed for D₁ depth and the highest (2.47 Cmol (p⁺) kg⁻¹) for D₃ depth. The exchangeable sodium content of the soil decreased from 3.66 Cmol (p⁺) kg⁻¹ for I₄ to 1.66 Cmol (p⁺) kg⁻¹ for I₁ dilution.

All the amendments used decreased the exchangeable sodium content of soil when compared to control. Among all the three depths, significantly higher exchangeable sodium content was found in I₄ (3.79 Cmol (p⁺) kg⁻¹) dilution of D₃ depth and lowest (1.61 Cmol (p⁺) kg⁻¹) was observed for I₁ dilutions of D₁ depth.

Interaction effects between C, IXA, AXD IXAXD were found significant. However, interaction effect between A and IXD were non significant.

4.13.4

The data on exchangeable potassium are presented in Table 21 and Fig 2. Significant differences in case of exchangeable potassium was noticed among the depths, dilution levels, amendments and their interactions.

The exchangeable potassium was decreased with depth having a highest (0.81 Cmol (p⁺) kg⁻¹) value at D₁ followed by D₂ and D₃ depths respectively. The exchangeable potassium content significantly increased as concentration of the effluent increased, the highest being 1.13 Cmol (p⁺) kg⁻¹ in I₁

Table 21 : Exchangeable potassium (C mol (Pt) kg-1) content of the soil due to soil column leaching with dilated distillery effluent and amendments

	D ₁				D ₂				D ₃				I							
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
C	1.050	0.800	0.450	0.225	0.529	0.900	0.670	0.300	0.175	0.689	0.740	0.540	0.230	0.695	0.888	1.330	0.357	0.417	0.720	0.706
G	1.290	0.950	0.610	0.355	0.800	1.150	0.830	0.410	0.265	0.663	1.030	0.700	0.300	0.190	0.654	1.367	0.882	0.413	0.510	0.793
G+P	1.650	1.250	0.800	0.490	0.856	1.400	1.010	0.540	0.365	1.121	1.200	0.920	0.410	0.295	0.706	1.017	1.357	0.540	0.375	0.822
P	2.350	1.350	0.950	0.505	1.280	2.000	1.700	0.800	0.515	1.253	1.550	1.000	0.620	0.395	0.891	0.787	1.180	1.260	0.293	0.880
Mean	1.315	0.763	0.624	0.535	0.809	1.060	1.066	0.575	0.461	0.791	1.000	1.003	0.774	0.428	0.789	0.125	0.944	0.658	0.475	
S.E.m± C.D.at 5%																				
A		0.024	0.069																	
B		0.023	0.067																	
C		0.020	NS																	
A X B		0.047	0.135																	
A X C		0.044	0.117																	
B X C		0.041	0.114																	
A X B X C		0.082	0.233																	

dilution and the lowest being $0.48 \text{ Cmol (p}^+) \text{ kg}^{-1}$ in I_4 dilution. Among the amendments pressmud recorded significantly higher exchangeable potassium ($0.88 \text{ Cmol (p}^+) \text{ kg}^{-1}$) as compared to other amendments.

The interaction effects between the levels of IXA, IXD, AXD and IXAXD were found to be significant while the interaction effect between the levels of D was found non significant.

4.13.5

The observation of exchangeable calcium are presented in Table 22 and Fig 1. The results revealed that the significant change in exchangeable calcium content was not only in dilutions and amendments but also in interactions including depths.

The highest exchangeable Ca content of $30.72 \text{ Cmol (p}^+) \text{ kg}^{-1}$ noticed at D_1 depth and decreased with depth. But the decrease in exchangeable Ca was not significant. The lowest ($27.75 \text{ Cmol (p}^+) \text{ kg}^{-1}$) and highest ($35.27 \text{ Cmol (p}^+) \text{ kg}^{-1}$) calcium content was recorded by I_4 and I_1 dilutions respectively. There was increase in exchangeable Ca content with the addition of the amendments and the highest exchangeable Ca was recorded by gypsum plus pressmud ($32.75 \text{ Cmol (p}^+) \text{ kg}^{-1}$).

Table 22 : Exchangeable calcium (C mol (Pt) kg⁻¹) content of the soil due to soil column leaching with dilated distillery effluent and amendments

	D ₁					D ₂					D ₃					I				
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
C	33.000	34.250	27.000	25.250	27.775	29.750	29.000	25.750	23.000	29.975	27.250	27.100	24.100	20.750	32.275	35.667	27.050	27.617	29.700	30.000
G	35.250	33.750	29.050	27.000	31.262	33.000	31.250	27.900	25.750	29.475	30.100	29.750	26.100	21.800	29.650	35.750	31.583	26.817	28.317	30.617
G+P	36.750	37.100	31.750	28.900	31.863	36.050	35.000	29.200	27.000	31.812	33.150	32.250	27.300	25.750	29.610	36.367	36.950	29.833	27.850	32.750
P	42.250	39.000	33.150	32.000	36.600	39.800	36.250	31.700	29.250	31.413	37.250	34.750	29.500	27.800	33.613	31.317	34.167	33.500	25.117	31.025
Mean	35.350	31.138	28.638	27.738	30.716	34.313	32.888	28.325	27.275	30.700	33.162	31.788	29.863	26.725	30.384	35.275	32.437	29.441	27.746	
S.E.m± C.D.at 5%																				
A					0.289					0.822										
B					0.282					0.819										
C					0.250					NS										
A X B					0.577					1.643										
A X C					0.508					1.426										
B X C					0.503					1.423										
A X B X C					1.000					2.846										

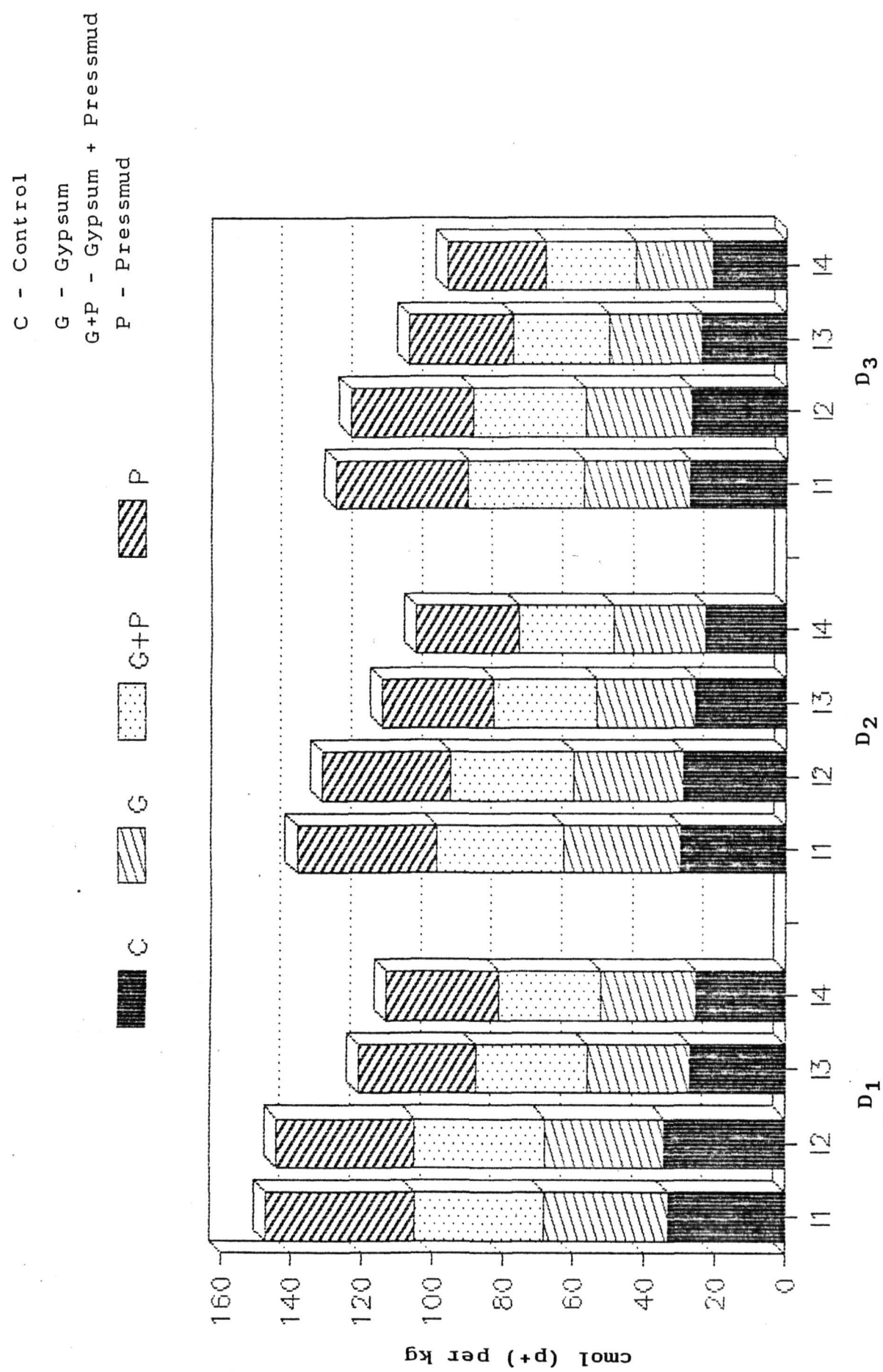


Fig 1: Exchangeable Calcium content of soil due to soil column leaching with diluted distillery effluent and amendment.

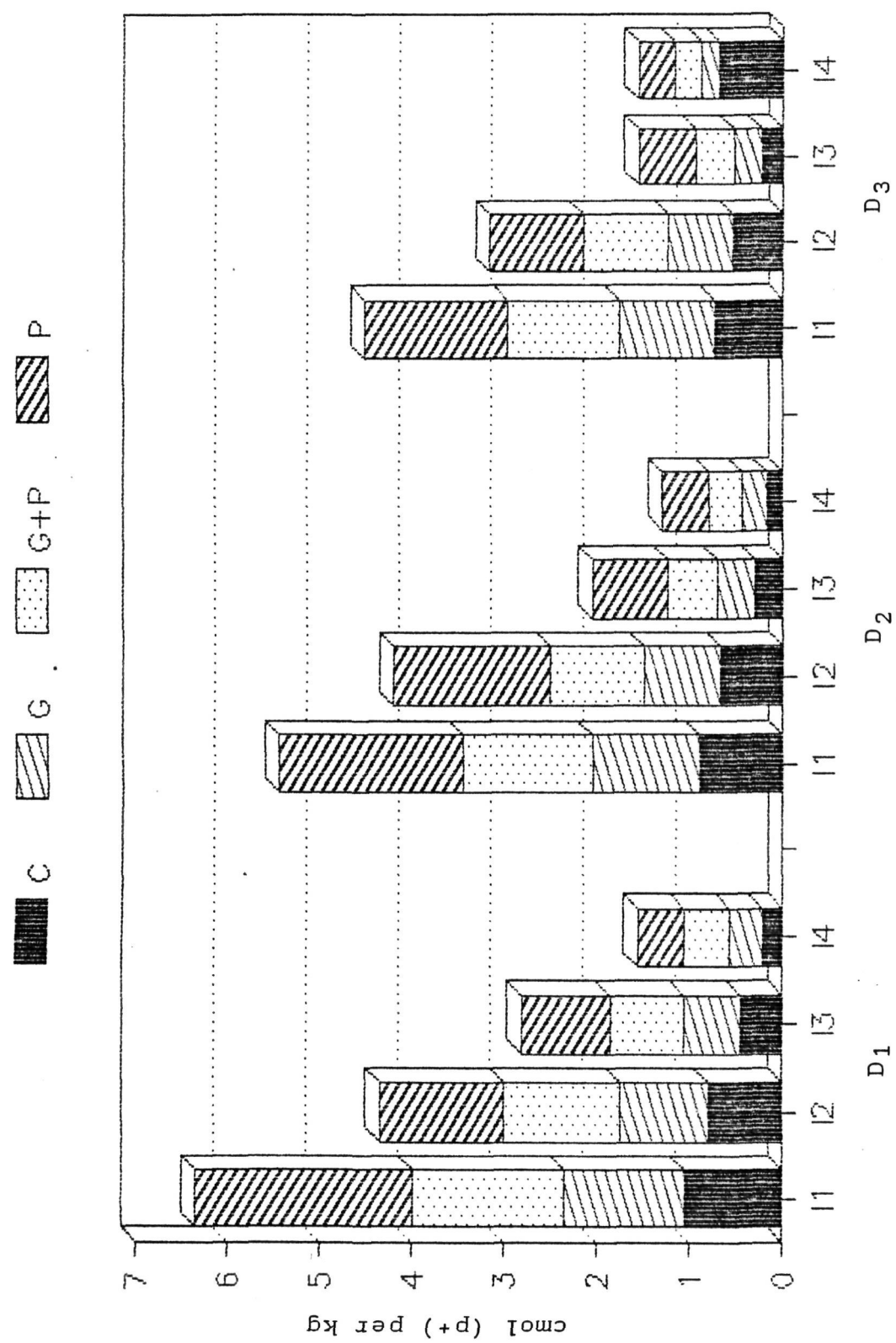


Fig 2: Exchangeable Potassium content of soil due to soil column leaching with diluted distillery effluent and amendment.

Interaction effects between the levels of IXA, IXD, AXD and IXAXD were found significant.

4.13.6

The data on exchangeable magnesium content are presented in Table 23. The effect of leaching of soil with different levels of effluent river water in respect of exchangeable Mg showed significant difference not only in dilution levels, amendments and depths but also in their interactions.

The exchangeable magnesium content of soil increased with depth from $7.87 \text{ Cmol (p}^+) \text{ kg}^{-1}$ to $8.19 \text{ Cmol (p}^+) \text{ kg}^{-1}$. The highest mean exchangeable Mg was found in I_4 ($9.75 \text{ Cmol (p}^+) \text{ kg}^{-1}$) and the lowest was in I_1 ($6.14 \text{ Cmol (p}^+) \text{ kg}^{-1}$).

Significant increase in exchangeable magnesium content was noticed with the addition of amendments.

Interaction effect between IXA, IXD, AXD and IXAXD was significant.

4.14.1

The data pertaining to soluble sodium are perused in Table 24 and Fig 3. The significant differences in soluble sodium was found in respect of various dilution levels of effluent with river water, amendments and interactions.

Table 23 : Exchangeable Magnesium (C mol {P+} kg-1) content of the soil due to soil column leaching with diluted distillery effluent and amendments

	D ₁										D ₂					D ₃					I					
	I ₁					I ₂					I ₃					I ₄										
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	
C	5.750	5.250	4.750	3.085	5.875	8.050	7.150	5.850	4.250	6.575	8.750	8.050	7.350	6.250	8.325	6.317	4.317	6.983	10.083	6.925						
G	6.150	5.450	4.950	4.350	9.275	8.350	7.250	6.350	4.950	6.225	9.950	9.450	8.750	7.350	6.875	6.317	7.450	6.150	9.917	7.450						
G+P	7.050	6.250	5.550	4.750	8.975	11.450	9.450	8.750	6.950	10.125	13.250	12.750	11.250	9.550	6.725	6.117	10.530	7.817	9.950	8.608						
P	8.250	7.350	6.950	5.950	7.375	13.050	10.750	9.250	7.750	9.450	15.350	13.650	12.350	10.250	10.825	5.817	9.150	12.850	9.050	9.217						
Mean	6.300	7.125	8.000	10.075	7.875	6.075	8.725	7.900	9.675	8.094	6.050	7.750	9.450	9.500	8.188	6.142	7.867	8.450	9.750							
S.E.m± C.D.at 5%																										
A		0.063	0.183																							
B		0.060	0.180																							
C		0.055	0.156																							
A X B		0.126	0.360																							
A X C		0.109	0.315																							
B X C		0.107	0.311																							
A X B X C		0.219	0.623																							

Table 24 : Soluble sodium (me/l) content of the soil due to soil column leaching with diluted distillery effluent and amendments

	D ₁										D ₂					D ₃					I																								
	I ₁					I ₂					I ₃					I ₄					I ₁					I ₂					I ₃					I ₄					Mean				
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean										
C	2.600	2.520	2.200	1.600	2.525	3.000	2.850	2.750	1.870	2.885	3.350	3.150	3.050	2.400	3.075	2.843	1.820	2.917	2.812	2.812																									
G	2.930	2.150	2.450	1.860	2.347	3.200	3.050	2.900	2.200	2.610	4.000	3.850	3.600	2.850	2.838	2.567	2.783	2.423	2.883	2.883																									
G+P	3.000	2.830	2.750	2.000	2.645	3.500	3.350	3.100	2.650	3.150	4.300	4.000	3.500	3.000	3.750	2.660	3.377	2.983	3.088	3.088																									
P	3.030	2.950	2.860	2.150	2.740	3.780	3.500	3.200	2.950	3.350	4.880	4.620	4.100	3.300	4.220	2.667	3.300	4.393	3.353	3.353																									
Mean	2.728	2.575	3.150	3.530	2.996	2.788	2.998	3.005	3.500	3.073	2.538	2.887	3.383	3.325	3.083	2.684	2.820	3.179	3.450	3.450																									
S.E.m± C.D.at 5%																																													
A		0.025	0.074																																										
B		0.220	0.071																																										
C		0.220	NS																																										
A X B		0.500	0.143																																										
A X C		0.430	0.126																																										
B X C		0.040	0.124																																										
A X B X C		0.087	0.247																																										

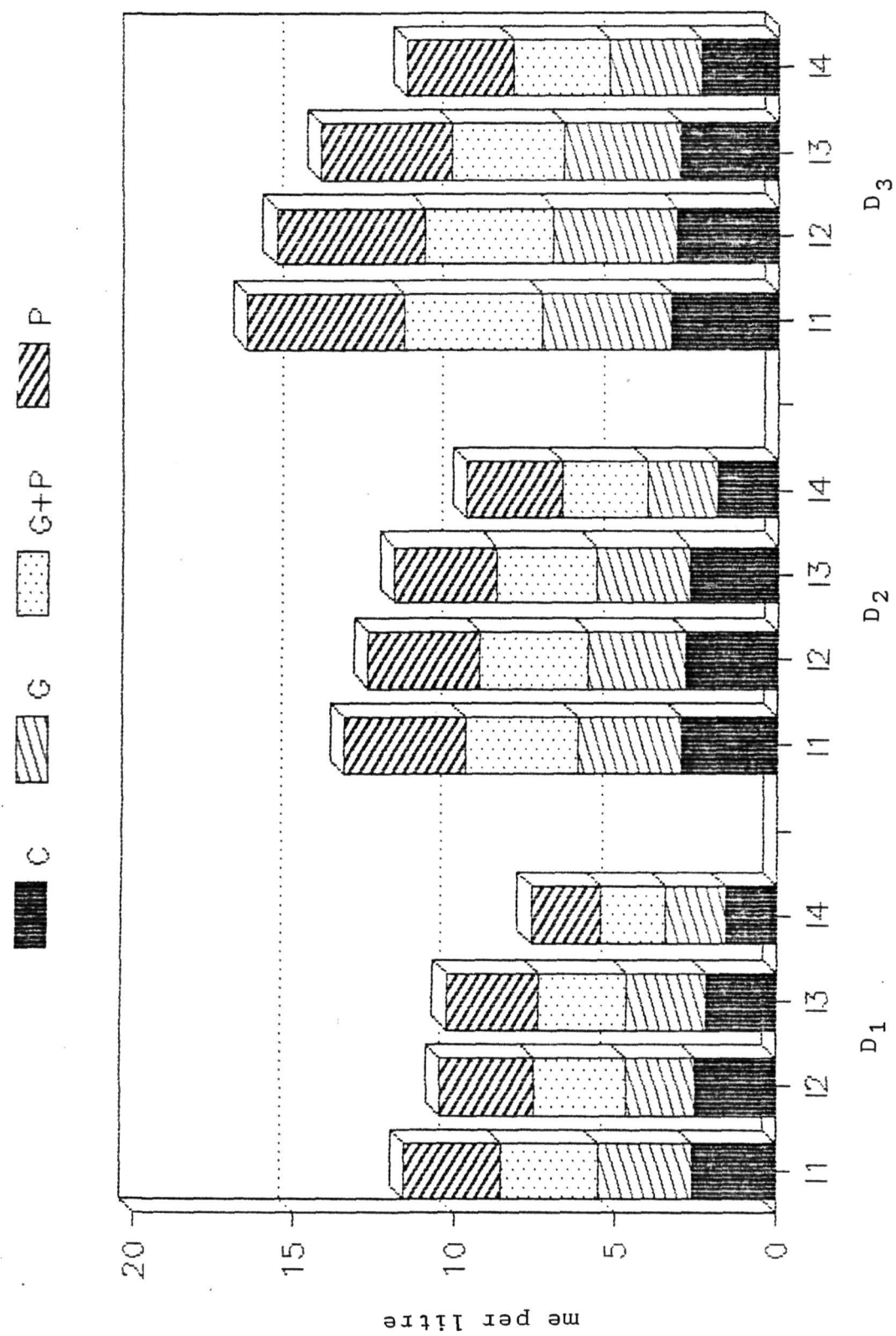


Fig 3: Soluble Sodium content of soil due to soil column leaching with diluted distillery effluent and amendment.

The soluble sodium content though increased with depth with the lowest value of 3.00 me/l at D₁ depth to 3.09 me/l at D₃ depth but difference is not significant. Generally the concentration of soluble sodium content found to increase as the concentration of effluent decreased. The lowest mean soluble sodium content was observed in I₁ dilution (2.68 me/l) and the highest in I₄ dilution (3.45 me/l). Among the amendments, the lowest soluble sodium of 2.81 me/l was noticed in control and the highest of 3.35 me/l was in pressmud. In the interaction of AXC, the soluble sodium content ranged from 2.54 me/l to 3.53 me/l.

The interaction effect between the levels of IXA, IXD, AXD and IXAXD were highly significant.

4.14.2

The data on soluble potassium are furnished in Table 25 and Fig 5. Significant differences incase of soluble potassium were noticed among depths, dilution levels, amendments and their interactions.

The soluble potassium decreased with depth having the highest (0.19 me/l) at D₁ depth followed by D₂ and D₃ depth. The soluble potassium content significantly increased as the concentration of effluent increased. The highest being 0.34 me/l in I₁ dilution. Among the amendments pressmud had significantly higher soluble K content (0.20 me/l) when

compared to other amendments. In the interaction of A X C the soluble potassium content ranged from 0.06 me/l in I₄ dilution of D₃ depth to 0.46 me/l in I₁ dilution of D₁ depth.

Interaction effect between IXA, IXD, AXD and IXAXD was found significant.

4.14.3

Table 26 and Fig 4. elucidate the data concerning to soluble Ca + Mg. There were significant differences among dilution levels, amendments and their interaction in respect of soluble Ca + Mg.

The highest soluble Ca + Mg in soil (0.91 me/l) at D₁ depth was on par with soluble Ca + Mg at D₂ and D₃ depths. There was significant increase in soluble Ca + Mg with the effluent dilutions application over Krishna river water. The difference in soluble Ca + Mg of soil amongst the effluent dilution was on par with each other.

Among the amendments the highest soluble Ca + Mg content under G + P (0.94 me/l) was on par with pressmud. The soluble Ca + Mg content increased significantly from 0.54 me/l. in I₄ dilution of D₃ depth to 1.28 me/l in I₁ dilution of D₁ depth.

Interaction effects were significant between the levels of IXA, IXD, AXD and IXAXD.

Table 26 : Soluble Ca + Mg (me/l) content of the soil due to soil column leaching with diluted distillery effluent and amendments

	D ₁					D ₂					D ₃					I				
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
C	1.180	1.050	0.580	0.673	0.870	1.060	0.850	0.520	0.220	0.818	0.900	0.720	0.460	0.200	0.970	1.413	0.373	0.643	0.850	0.820
G	1.400	1.200	0.700	1.950	1.312	1.260	1.060	0.640	0.350	0.827	1.050	0.880	0.520	0.300	0.833	1.383	0.990	0.533	0.727	0.908
G+P	1.660	1.350	0.950	0.995	1.238	1.460	1.080	0.770	0.470	1.190	1.240	0.950	0.700	0.120	0.633	1.177	1.327	0.647	0.607	0.939
P	1.900	1.600	1.200	0.778	1.360	1.670	1.420	1.030	0.570	1.172	1.350	1.200	0.920	0.490	1.115	0.950	1.188	1.213	0.403	0.938
Mean	1.283	0.860	0.768	0.910	0.910	1.250	1.040	0.668	0.670	0.907	1.160	0.843	0.843	0.540	0.888	1.237	0.969	0.759	0.647	
S.E.m± C.D.at 5%																				
A	0.180	0.054																		
B	0.170	0.052																		
C	0.160	NS																		
A X B	0.380	0.108																		
A X C	0.037	0.093																		
B X C	0.330	0.191																		
A X B X C	0.660	0.187																		

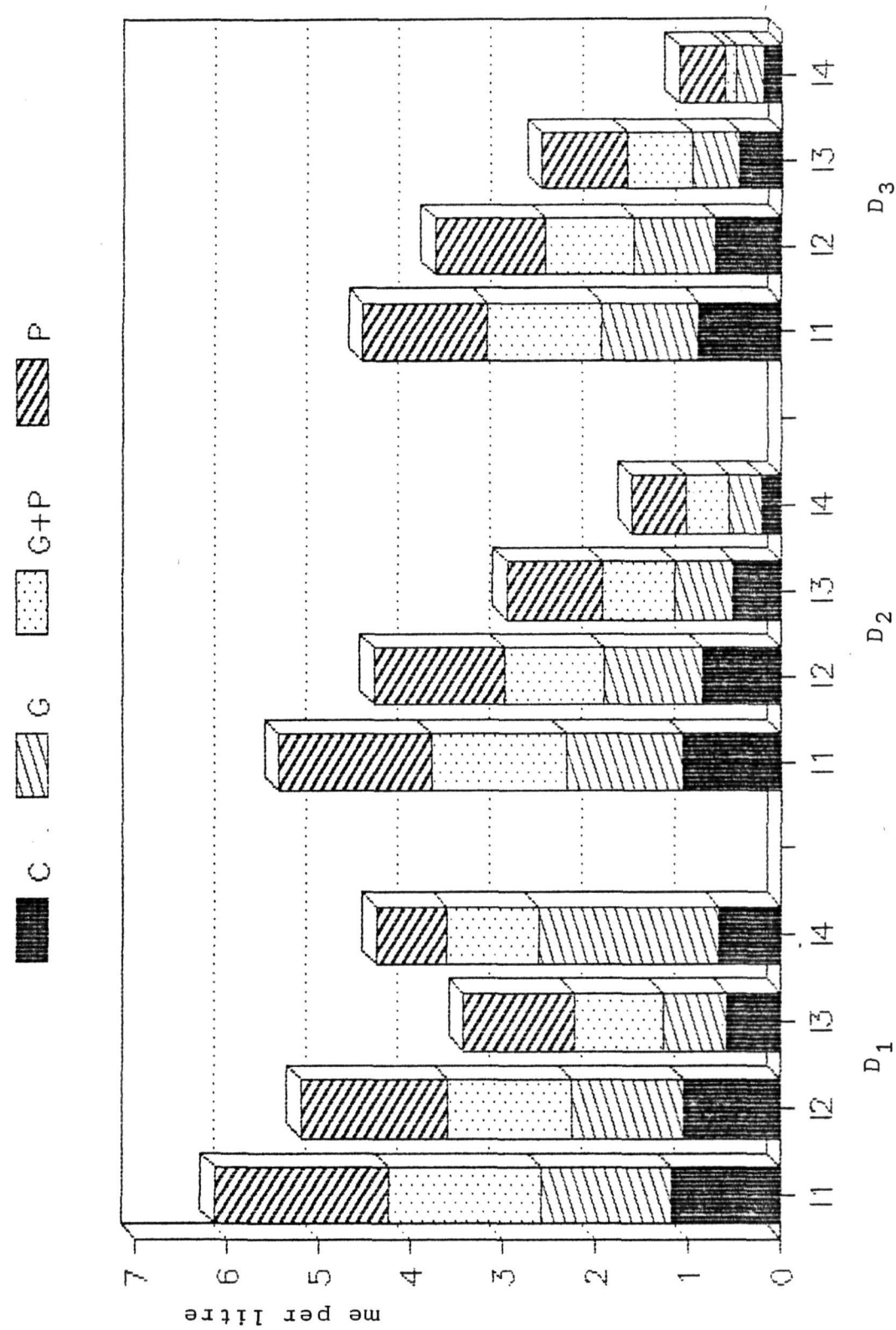


Fig 4: Soluble Ca + Mg content of soil due to soil column leaching with diluted distillery effluent and amendment.

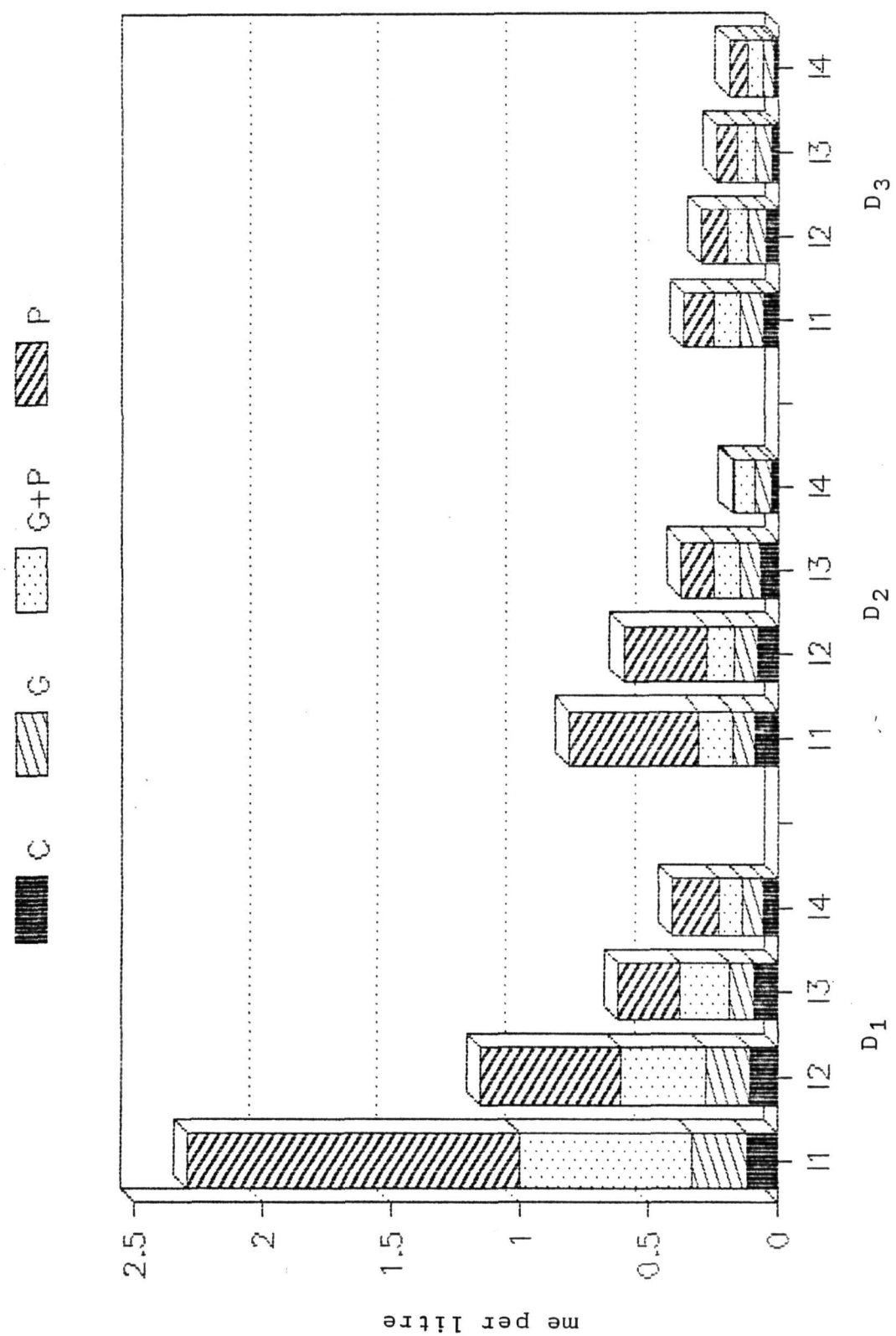


Fig 5: Soluble Potassium content of soil due to soil column leaching with diluted distillery effluent and amendment.

4.14.4

The data on soluble bicarbonate are furnished in Table 27. Incase of soluble bicarbonate, significant differences among depths, dilution levels, amendments and their interactions were noticed.

The soluble bicarbonate content increased with depth and it ranged from 1.87 me/l at D₁ depth to 2.49 me/l at D₃ depth. The difference in soluble bicarbonate content at D₂ and D₃ depths were not significant. Increasing trend of soluble bicarbonate content was noticed with decrease in dilution level. The highest being 2.36 me/l in I₁ dilution and lowest 1.46 me/l in I₄ dilution. Among the amendments control had significantly lowest soluble bicarbonate (1.47 me/l) content and pressmud recorded significantly highest soluble bicarbonate content (2.44 me/l). The soluble bicarbonate content ranged from 1.39 me/l in I₄ dilution of D₃ depth to 2.51 me/l in I₁ dilution of D₁ depth. I₃ and I₄ dilutions in D₁ depth were on par with each other.

The interaction effect were significant between the levels of IXA, IXD, AXD and IXAXD.

4.14.5

The data on soluble chloride are given in Table 28 and Fig 6. Soluble chloride content significantly differed among dilution levels, amendments and in their interactions.

Table 27 : Soluble bicarbonate (me/l) content of the soil due to soil column leaching with diluted distillery effluent and amendments

	D ₁					D ₂					D ₃					I				
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean
C	0.300	0.520	0.700	0.850	0.595	0.520	1.060	0.880	1.380	0.960	1.300	0.850	1.950	2.330	1.983	2.500	1.467	0.567	1.367	1.475
G	0.580	1.020	1.350	1.400	1.087	0.840	1.890	1.460	2.000	1.547	2.050	1.300	2.350	2.580	2.070	2.450	1.303	1.527	1.550	1.708
G+P	0.820	1.350	1.700	1.850	1.430	1.320	2.450	2.060	2.930	2.190	2.000	2.350	3.200	3.750	2.775	2.317	1.853	2.563	1.523	2.064
P	1.200	1.860	2.350	2.600	1.698	1.910	3.360	2.550	3.700	2.475	3.300	2.910	4.600	4.450	3.145	2.187	3.593	2.567	1.410	2.439
Mean	0.725	1.833	1.580	1.542	1.867	2.325	2.027	1.910	1.450	1.928	2.420	2.253	1.810	1.395	2.492	2.363	2.054	1.806	1.463	
S.E.m± C.D.at 5%																				
A		0.019	0.054																	
B		0.016	0.052																	
C		0.016	0.047																	
A X B		0.038	0.108																	
A X C		0.033	0.093																	
B X C		0.031	0.090																	
A X B X C		0.066	0.187																	

Table 28 : Soluble chloride (me/l) content of the soil due to soil column leaching with diluted distillery effluent and amendments

D ₁				D ₂				D ₃				I			
I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	
C	1.180	1.080	0.800	0.510	0.890	2.040	1.660	1.470	1.000	1.542	2.590	2.350	2.075	1.520	1.878
G	1.350	1.310	1.200	0.710	1.140	2.190	2.040	1.800	1.320	2.957	3.240	3.550	2.310	1.730	1.782
G+P	1.700	1.420	1.350	0.750	1.305	2.550	2.150	2.060	1.520	2.280	3.680	3.000	2.620	2.100	2.850
P	1.900	1.660	1.460	0.800	1.450	2.700	2.300	2.150	1.710	2.320	3.950	3.200	3.050	2.550	3.187
Mean	2.475	2.095	1.475	1.425	1.190	2.694	2.048	1.900	1.360	2.000	2.480	2.340	2.720	1.318	2.718
S.E.m± C.D.at 5%															
A	0.047	0.135													
B	0.040	0.130													
C	0.041	NS													
A X B	0.095	0.270													
A X C	0.082	0.234													
B X C	0.080	0.230													
A X B X C	0.164	0.467													

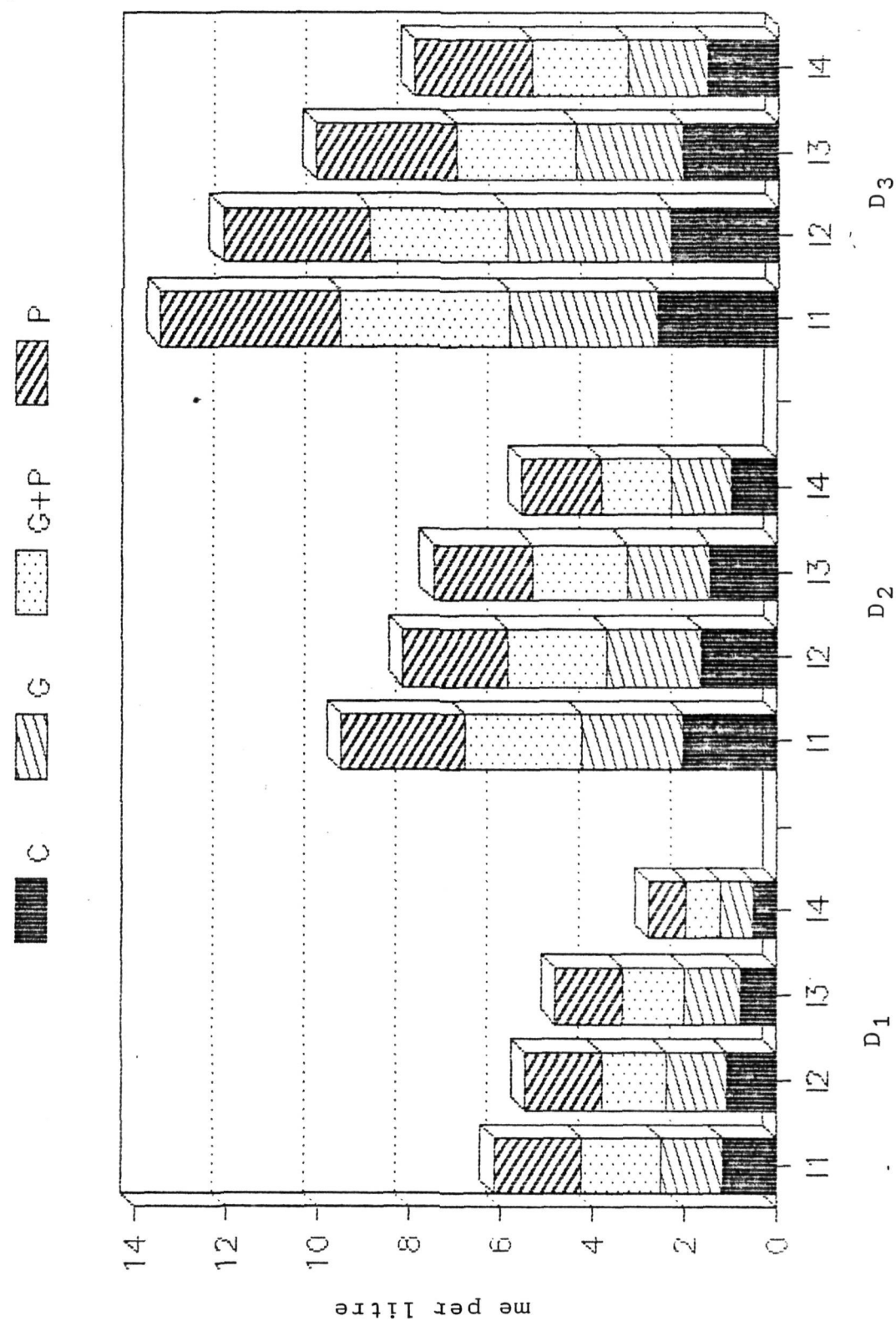


Fig 6: Soluble Chloride content of soil due to soil column leaching with diluted distillery effluent and amendment.

The soluble chloride content remained significant at all the depths. The range of soluble chloride was from 1.49 (D₁) to 2.70 me/l (D₃). The soluble chloride content decreased significantly at higher dilution level of effluent with river water. The lowest mean soluble chloride of 1.37 me/l was recorded under I₄ dilution. Whereas, the highest of 2.51 me/l was in I₁ dilution. Among the amendments unamended control was found to contain the lowest 1.70 me/l soluble chloride whereas the highest (2.31 me/l) soluble chloride was noticed in pressmud. The chloride content under non amended treatment was same as that under gypsum application.

The interaction effects were found significant between the levels IXA, IXD, AXD and IXAXD.

4.14.6

The data on soluble sulphate content of soil leached with the different levels of effluent dilution and amendments are given in Table 29. The change in the soluble sulphate content of soil column leached with different level of lagoon spentwash mixed river water and amendments showed significant differences not only in depths, dilution levels, amendments but also in their interactions.

The soluble sulphate content increased with depth and the increase in soluble sulphate content of soil at D₁ and D₂ remained on par with each other. The variation in soluble

Table 29 : Soluble sulphate (me/l) content of the soil due to soil column leaching with diluted distillery effluent and amendments

	D ₁										D ₂					D ₃					I					
	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	I ₁	I ₂	I ₃	I ₄	Mean	
C	0.940	0.650	0.400	0.145	0.714	1.110	1.010	0.620	0.290	0.969	1.290	1.150	0.950	0.540	1.293	0.193	0.580	1.000	0.980	0.938						
G	1.360	1.000	0.480	0.300	1.025	1.540	0.120	0.865	0.490	0.750	1.650	1.350	1.130	0.650	1.076	1.503	0.878	0.318	1.220	0.980						
G+P	1.360	1.150	0.940	0.510	1.253	1.580	1.300	1.150	0.730	1.075	2.150	2.010	1.550	0.850	0.846	1.067	0.833	1.380	0.883	1.046						
P	1.290	1.100	0.500	0.350	0.995	1.550	1.240	0.960	0.480	1.310	1.570	1.500	1.170	0.650	1.026	0.717	1.790	1.247	0.640	1.098						
Mean	1.231	0.990	0.965	0.819	0.997	1.080	1.060	1.012	0.946	1.026	1.125	1.083	1.075	0.815	1.860	1.125	1.020	0.986	0.931							
S.E.m† C.D.at 5%																										
A		0.013	0.037																							
B		0.010	0.030																							
C		0.110	0.032																							
A X B		0.260	0.073																							
A X C		0.220	0.064																							
B X C		0.020	0.060																							
A X B X C		0.045	0.127																							

sulphate concentration with depth was observed. The highest of 1.06 me/l soluble sulphate content at D₃ depth was significantly superior to soluble sulphate at D₁ and D₂ depths. The soluble sulphate content of soil was increased significantly from 0.93 me/l in I₄ dilution to 1.12 me/l in I₁ dilution. Among the amendments used, soluble sulphate content of all the amendments was higher than control. The soluble sulphate content of amendments differed significantly with one another. The highest soluble sulphate content was found in pressmud amendment (1.10 me/l).

The interaction effect was significant between the levels of IXA, IXD, AXD and IXAXD.

DISCUSSION

V. DISCUSSION

The results of the field experiment and soil column leaching study to know the effect of Ugar Sugar distillery effluent dilution irrigation on soil properties, crop yield and uptake of nutrients in presence of amendments and changes in soil pH, EC, exchangeable cations and anions are discussed below.

5.1 Effect of distillery effluent irrigation on chemical properties of soils after the harvest of sugarcane, wheat and maize during rabi season

5.1.1 pH

Irrigating the soil with different ratios of lagoon spentwash : river water and application of amendments indicated that the pH of soil decreased with increase in the concentration of effluent in irrigation water. The pH under 1:10 effluent dilution decreased significantly when compared to other treatments. The decrease in pH under 1:10 effluent dilution is attributed to the low pH of the distillery effluent when compared to river water. Moreover, lagoon spentwash contained more of calcium and sulphate which might have precipitated as calcium sulphate, which acts as buffer in maintaining the pH. Similar findings were reported by Singh (1961).

Among the amendments pressmud treatment was found to be better in reducing the soil pH. This reduction in pH might be due to the application of larger quantity of pressmud (24 ton/acre) which contains acid forming material.

The pH of soil after the harvest of wheat under 1:10 effluent dilution and pressmud was the lowest compared to 0 : 100 effluent dilution. The reduction in pH in pressmud treatment may be due to replacement and removal of sodium from exchange complex. Rajannan *et al.* (1979) reported significant reduction of pH in case of alkali soils at higher levels of pressmud (10 tons/ha).

5.1.2 Electrical conductivity

Soils irrigated with different ratios of lagoon spentwash : river water indicated that EC of soil increased significantly with decrease in dilution level indicating higher EC in 1:10 effluent dilution. This increase in EC is attributed to higher EC of lagoon spentwash which contains higher electrolyte concentration. The present findings are in agreement with findings of Jadhav and Savant (1975), Shindhe *et al.* (1993).

The EC of soil increased with the use of amendments. Use of pressmud significantly increased the electrical conductivity of soil. The increase in EC under pressmud alone can be ascribed to EC of sulphitation of pressmud (Gupta *et al.*, 1987).

Higher EC in 1:10 effluent dilution with pressmud application after the harvest of sugarcane crop may be due to more salt present in lagoon spentwash which is more in 10 time effluent dilution compared to other treatments as well as release of electrolyte by degradation of pressmud.

5.1.3 Organic carbon

Irrigating the soils with different dilutions of lagoon spentwash mixed river water indicated that organic carbon status of soils increased significantly with the increase in concentration of effluent. The highest OC percentage was recorded under 1:10 effluent : river water dilution which could be due to higher OC content of the effluent (Appendix).

Among the amendments pressmud application recorded significantly higher OC percentage. The pressmud contains decomposable organic matter which on decomposition increases the content of OC in the soil when compared to the treatment without pressmud amendment.

5.1.4 Available nitrogen

The available nitrogen content of the soil increased significantly with the use of diluted effluent irrigation. The mixture of effluent : Krishna river water in 1:10

effluent dilution increased the available nitrogen status of the soil when compared to control. This could be attributed to the higher organic matter content of effluent which on decomposition increases the nitrogen content of the soil.

Use of pressmud also increased the the available nitrogen status of soil significantly. This is due to mineralisation of pressmud which helped in increasing the available nitrogen status of soils.

5.1.5 Available P_2O_5

Available P_2O_5 content of the soil increased with the use of diluted effluent for irrigation. The highest available P_2O_5 content of the soils was recorded by 1:10 effluent dilution. This could be attributed to the higher phosphorus content of effluent which is in higher proportion in 10 times dilution than rest of the higher effluent dilutions.

Application of pressmud significantly improved the phosphorus status of soil. This is mainly due to release of phosphorus by the process of mineralisation of pressmud.

The interaction of 1:10 effluent dilution X pressmud for wheat and maize soils was significant which is due to release of available P_2O_5 from both the effluent and amendment.

5.1.6 Available potassium

Available potassium content of soil treated with different levels of lagoon spentwash mixed river water and amendments revealed that there was increase in available potassium of soils with the use of effluent water. Among the different dilutions, 1:10 effluent : river water dilution recorded the highest available potassium when compared to control and other effluent dilutions. It may be due to supply of potassium from lagoon spentwash which contained very high amount of total potassium (8700 mg/l). Hence lower the dilution, more will be the accumulation of available potassium. Similar results were also reported by Pawar *et al.* (1992).

Among the amendments, pressmud was found to accumulate more of available potassium as compared to other amendments. Such an increase may be attributed to potassium content of pressmud which is 0.31 per cent.

Dilution level and amendment interaction showed significant difference with respect to available potassium. The available potassium was observed to be highest in 1:10 effluent dilution with pressmud amendment. Such an increase in available potassium may be attributed to presence of higher potassium in effluent and mineralisation of pressmud.

5.1.7 Exchangeable sodium

Effluent irrigation of various dilution resulted in increase in exchangeable sodium content over control. Lower exchangeable sodium content was noticed in soils irrigated with 1:10 effluent dilution. This could be attributed to higher concentration of calcium available in 1:10 effluent dilution for replacement of exchangeable sodium. Lagoon spentwash contained higher amount of calcium (1920 mg/l) than sodium (700 mg/l). Calcium being divalent possesses higher replacing power might have displaced sodium from exchangeable complex. This brings in the reduction of exchangeable sodium content. The reduction in exchangeable sodium with diluted effluent irrigation is in corroboration with the report of Pawar *et al.* (1992).

Among the amendments, pressmud significantly decreased the exchangeable sodium content of soils. This could be attributed to the use of more calcium which is present in organic form in pressmud. This presence of higher calcium in soil solution might have replaced sodium from exchangeable complex. Hence reduction in exchangeable sodium was more pronounced in pressmud application. Reduction in exchangeable sodium by gypsum amendment over control is due to supply of calcium with gypsum which displaces sodium from exchangeable complex. The beneficial effects of pressmud is to supply calcium on decomposition

and improvement in soil physical condition (Puttaswamy Gowda and Pratt, 1973).

In the interaction effect between effluent dilution and amendment lowering of exchangeable sodium was observed in 10 times dilution of effluent with pressmud. This could be attributed to the presence of higher concentration of calcium in 1:10 effluent dilution and release of calcium from pressmud, thus replacing sodium from exchangeable complex.

5.1.8 Exchangeable calcium

The exchangeable calcium content of soil irrigated with different levels of lagoon spentwash : Krishna river water resulted in higher exchangeable calcium under 1:10 effluent dilution when compared to other dilutions and control. As the concentration of effluent added increases, more and more addition of calcium takes place which in turn helps for higher adsorption of calcium. Lagoon spentwash contained higher amounts of calcium (1920 mg/l) which might have resulted in higher accumulation of calcium. The present findings are in accordance with the report of Ramanathan *et al.* (1977) who noticed higher concentration of calcium in soils irrigated with sewage.

Among the amendments, significant increase in exchangeable calcium was noticed in pressmud plus gypsum amendment. Increased soluble calcium in the media due to

enhanced solubility of gypsum in presence of pressmud might have resulted in more adsorption of calcium under gypsum plus pressmud amendment. Increase in supply of soluble form of calcium from gypsum and pressmud is reported by Puttaswamy Gowda and Pratt (1973), Golden (1975) and Prasad (1976), also reported increase in availability of calcium in soil due to filter pressmud application. The interaction of effluent mixed river water and amendment on exchangeable calcium under 1:10 effluent dilution and gypsum plus pressmud ascribed to the addition of calcium through effluent and soluble calcium from gypsum and pressmud. Gupta *et al.* (1987) observed higher content of calcium in pressmud.

5.1.9 Exchangeable magnesium

The higher accumulation of exchangeable magnesium with higher dilution of effluent observed might be attributed to the preferential adsorption of magnesium over calcium. The reduction of exchangeable magnesium by spentwash application now recorded is in agreement with the findings of Pawar *et al.* (1992), Jadhav and Savant (1975).

Exchangeable magnesium content of soil under pressmud was higher than other two amendment treatments. The decrease in exchangeable magnesium under gypsum and gypsum plus pressmud may be due to lesser quantity of magnesium present in gypsum.

5.2 Grain yield of crops

Generally the response of crops differ for different effluent dilutions.

5.2.1 Maize

Maize recorded significantly higher yield of grain with the use of higher concentration of effluent water. The highest grain yield was recorded by maize under 1:10 effluent dilution. Since 10-times diluted effluent is rich in all the nutrients, the maize crop took up more nutrients from these plots and resulted in higher grain yield.

Pressmud releases plant nutrient during decomposition. This mineralized nutrients might have helped for higher corn yield. The nutrients through effluent might have resulted in more grain yield.

5.2.2 Wheat

The wheat crop recorded higher grain yield under 1:50 effluent dilution. Under 1:10 and 1:25 effluent dilution, the grains formed were not bold and were chaffy resulting in lesser weight. The grains formed under 1:50 effluent dilution were bold and the quality of seeds was good. Ten times diluted effluent contain higher nutrient. These nutrients might have used for putting up of vegetative growth resulting in lesser grain yield compared to higher

effluent dilutions. Different crops respond differently to the levels of nutrients. Since the pressmud is a source of all nutrients, wheat plants utilized these nutrients and produced more grain yield.

5.2.3. Sugarcane yield

The sugarcane crops recorded significantly higher cane yield under 1:10 effluent dilution. Sugarcane being long duration crop, had received more number of irrigation (12). Distillery effluent contains sizable amounts of K, P and other plant nutrients. Lower dilution of this effluent means higher nutrient supply than further dilutions. This increase in plant nutrients in 1:10 effluent dilution might have resulted in more cane weight per hectare.

Like distillery effluent pressmud also contains certain amounts of plant nutrients. Thus application of pressmud must have supplied more nutrients which are essential for plant growth resulting in higher cane weight.

5.3 Straw yield of crops

5.3.1 Maize straw yield (Rabi)

Maize is heavy feeder and took up more nutrients from 1:10 effluent dilution. Higher concentration of nutrients in lower dilution of effluent has supplied more nutrients to the maize. so higher maize straw yield was

noticed under 1:10 effluent dilution rather than higher dilution which lowers the nutrient concentration in the irrigation water. Application of pressmud supplied comparatively more nutrients than gypsum to soil resulting in more uptake of nutrients and straw yield.

5.3.2 Wheat (Rabi)

Wheat crop had put up more vegetative growth under 1:10 effluent dilution when compared to other treatments. This increased vegetative growth is attributed to the higher nutrient concentration in 10 times effluent dilution compared to 25 and 50 times effluent dilution. This resulted in more straw yield of wheat.

Likewise pressmud also releases many plant nutrients on mineralization which are essential for plant growth. This enhanced availability of plant nutrients from pressmud might have resulted in higher yield of wheat straw.

5.4 Plant nutrient uptake

Data pertaining to uptake of nutrients by crops (Tables 13 to 17) revealed that, there was higher uptake of all nutrients (N, P, K, Ca and Mg) under 1:10 effluent dilutions. Reason for higher uptake is because the concentration of these nutrients is higher in 1:10 effluent dilution compared to the effluent dilutions used Krishna

river water. Pressmud being organic waste, releases most of the plant nutrients by decomposition of organic matter. Hence uptake is more in pressmud treated plot compared to Krishna river water and unamended treatments.

5.4.1 Nitrogen

5.4.1.1 Sugarcane and Maize

There was significant increase in the uptake of nitrogen by sugarcane and maize with the use of diluted effluent irrigation. The plants under 1:10 effluent dilution recorded significantly higher uptake of N. This could be attributed to the higher nutrient supply in the lower dilution of effluent which contains more nutrients than 25 and 50 times dilution of effluent.

Application of pressmud significantly increased the N uptake which may be due to N content in pressmud.

The interaction effects of effluent dilution and pressmud in sugarcane and maize were significant which is due to higher N supply by 1:10 effluent dilution and pressmud.

5.4.1.2 Wheat

There was significant increase in the uptake of nitrogen due to diluted effluent irrigation by wheat crop. The total uptake of N was found higher in 1:10 effluent

dilution though the grain yield of wheat was more in 1:50 dilution. The plants under 1:10 effluent dilution had put up more of vegetative growth and also the movement of N from source to sink might have reduced.

The application of pressmud significantly increased the uptake of N. This could be due to availability of N on decomposition of pressmud.

5.4.2 Total phosphorus

5.4.2.1 Sugarcane and maize

There was significant increase in the uptake of total phosphorus by sugarcane and maize crops with the use of diluted distillery effluent irrigation. Both sugarcane and maize recorded significantly higher uptake of phosphorus under 1:10 effluent dilution. Since 1:10 effluent dilution contains more amount of distillery effluent which contains more of P when compared to Krishna river water used for diluting effluent. The higher P in 1:10 effluent dilution might have resulted in more uptake of P under this dilution.

Application of pressmud significantly improved the uptake of P. Which could be due to higher phosphate content in pressmud compared to other amendments tried.

The interaction between dilution and amendment was significant indicating supply of more of phosphate from pressmud and distillery effluent.

5.4.2.2 Wheat

There was significant increase in the uptake of P by wheat crop due to effluent dilution. The highest total uptake of P was found in 1:10 effluent dilution. This could be due to higher amount of P present in effluent under 1:10 effluent dilution compared to other dilution ratios. The movement of P from source to sink was badly affected as revealed by higher wheat grain yield under 1:50 effluent dilution.

5.4.3 Total potassium

5.4.3.1 Sugarcane and maize

Significant increase in the uptake of total potassium by sugarcane and maize crops was observed with the use of diluted distillery effluent irrigation. The plants under 1:10 effluent dilution recorded significantly higher uptake of potassium. The distillery effluent contains higher amounts of K. The higher K supply through lower effluent dilution must have rendered more uptake of K from 1:10 effluent dilution compared to other higher ratios of effluent dilutions.

Pressmud being a organic waste contains more of K compared to gypsum. Hence there was more uptake of K from pressmud amended soils.

The interaction of pressmud and dilution was significant. This indicates supply of more of K from pressmud and higher concentration of effluent i.e., 1:10 effluent dilution than rest of the treatment interaction.

5.4.3.2 Wheat

There was significant increase in the uptake of K by wheat crop due to effluent irrigation. The plants under 1:10 effluent dilution recorded significantly higher uptake of K when compared to other dilution ratios. This could be attributed to higher K content in lower effluent ratio. Yield of wheat was higher under the effluent dilution of 50 times. The ratio of straw to grain was higher under 1:10 effluent ratio indicating the reduction of K transport from source to sink.

Application of pressmud significantly improved the uptake of K by wheat crop which could be due to supply of K present in the pressmud.

5.4.4 Calcium

5.4.4.1 Sugarcane and maize

There was significant increase in the uptake of calcium by sugarcane and maize crops with the use of effluent

irrigation. The plants under 1:10 effluent dilution recorded significantly higher uptake of Ca. This could be attributed to the fact that the 1:10 effluent dilution contains proportionately higher Ca compared to 1:25, 1:50 effluent dilution and river water. Thus there was more uptake of Ca in 1:10 than rest of the irrigation treatments.

There was significant increase in the uptake of calcium by sugarcane and maize crops in pressmud applied plots. Gypsum also contains Ca, but the availability of Ca and Mg from pressmud is more because it is in organic matter and calcium is released during decomposition. so sugarcane and maize must have made use of this released Ca than Ca from $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ which releases Ca by chemical degradation.

5.4.4.2 Wheat

As was observed in case of many nutrients, Ca uptake by wheat is highest under treatment which received 10 times diluted effluent irrigation. This is because concentration of Ca is more in 1:10 effluent dilution compared to other irrigation treatments.

Uptake of Ca by wheat was more in pressmud applied plots compared to other amendment treatments. This higher Ca uptake under pressmud treatment is attributed to the release of Ca from pressmud due to its decomposition.

5.4.5 Magnesium

5.4.5.1 Sugarcane and maize

Significant increase in the uptake of magnesium by sugarcane and maize crops was observed with the use of effluent irrigation. The plants under 1:10 effluent dilution recorded significantly higher uptake of Mg. Distillery effluent contains higher amount of Mg compared to Krishna river water used to dilute the effluent. Since Mg content in 1:10 effluent is higher than 1:25 and 1:50 effluent dilution and Krishna river water, uptake by these crops is more under 1:10 effluent dilution.

The pressmud contains Mg, hence there was more of uptake of Mg from pressmud amended soils.

5.4.5.2 Wheat

Significant increase in the uptake of Mg by wheat crop was noticed due to effluent irrigation. The higher amount of total Mg uptake was seen in 1:10 effluent dilution plots which could be due to the higher amount of Mg present in effluent water. The more accumulation of total Mg in the wheat straws of 1:10 effluent dilution might reveal that the movement of Mg from straw to grain was affected.

Application of pressmud significantly improved the uptake of Mg by wheat plants which might be due to higher amount of Mg present in the pressmud.

5.4.6 Soil column leaching studies

Leaching of the soil column with different ratio's of spentwash : river water and amendments, gypsum, gypsum plus pressmud and pressmud indicated that the pH of the soils increased with depth. This increase in pH with depth due to different levels of effluent in irrigation water may be due to higher accumulation of sodium and bicarbonate with depth. The pH under I_1 significantly reduced from 8.23 to 7.86. The reduction in pH with increase in higher ratio of effluent was due to the low pH of effluent compared to river water. Moreover, lagoon spentwash contained more of calcium and sulphate which might have precipitated as calcium sulphate. The calcium sulphate acts as buffer in maintaining the pH. Similar findings were reported by Singh (1961).

The I_1 dilution had the lowest pH of 7.86 compared to I_4 dilution at the corresponding depth of D_1 . I_4 dilution contained more of Na (55 mg/l) than calcium (33.40 mg/l). Among the amendments, pressmud was found to be better in reducing the pH of the soil when compared to other amendments. This could be attributed to the higher amount of Ca present in pressmud which maintains the pH around neutral.

The interaction between irrigation and depth recorded the lowest pH under I_1 dilution. Similarly, at D_1

and D₂ depths also, distinct reduction in pH was found in I₁ dilution. The interaction of amendment and depth also recorded the lowest pH in I₄ dilution under all depths. These results are in agreement with the findings of Duraiswamy *et al.* (1986) in alkali soils.

Irrespective of depth, the pH under I₁ X P was the lowest compared to I₄ X C. The reduction in pH under pressmud may be due to replacement and removal of sodium from exchange complex by calcium and organic acid production during microbial degradation. Ramamoorthy and Agarwal (1986) stated that organic matter stimulated microbial activity and caused lowering of pH of alkali soil by producing organic acids. Indiraraja and Raj (1979) also reported significant reduction of pH in case of alkali soil at higher level of pressmud (10 tons/ha).

The observed increase in EC with depth due to leaching of soils with effluent : river water may be attributed to leaching of salt from surface layer and its accumulation at lower layers. The EC of soil was significantly increased with decrease in effluent dilution of 10 times (I₁) than only Krishna river water. This increase in EC may be due to higher EC of lagoon spentwash which contains higher electrolyte concentration. The present findings are in agreement with findings of Jadhav and Savant (1975), Shindhe *et al.* (1993). Addition of amendments improves soil

structure and helps in movement of salts in enabling the leaching out of salts from profile.

The application of pressmud was found to cause higher Ec of soils than other two amendments. Increase in EC under pressmud alone can be ascribed to EC of sulphitation of pressmud (Gupta *et al.*, 1987). Higher EC in the interaction between 10 times effluent dilution and pressmud than only river water and gypsum, may be due to more salt present in lagoon spentwash mixed river water as well as from pressmud. The highest EC was found in D₃ depth of I₁ dilution with pressmud and lowest in D₁ depth.

It is evident that salt from surface layer moved down along with irrigation water and accumulated in lower depths and amendments might have helped for easy movement due to improvement of physical condition of soils.

The increase in exchangeable sodium with depth due to effluent dilution and amendments may be attributed to the removal of exchangeable sodium from surface layer by irrigation water and its accumulation at lower depths. Longencecker and Lyearly (1959) noticed rapid increase in exchangeable sodium with depth in profiles of irrigated soil. Irrespective of depth, leaching with only river water has resulted in higher exchangeable sodium in soil column compared to leaching with different effluent dilutions,

because the sodium content of river water is more than effluent dilutions. It is in agreement with the report of Pawar *et al.* (1992). All the amendments brought down the exchangeable sodium content to a lower level and is attributed to the exchange of Na by the Ca present in gypsum and pressmud.

In the interaction of depth and amendment, pressmud, at all the three depths, recorded lower exchangeable sodium content than other amendment with depths. The reduction in exchangeable sodium under I₁ X P was significantly more over other amendments. The more reduction in exchangeable sodium recorded in surface soil than the layers below is due to comparatively more intensive leaching of surface layer in presence of amendments and higher Ca + Mg content in distillery effluent.

Lower exchangeable sodium was noticed in soils leached with I₁ dilution is attributed to higher concentration of calcium available in I₁ dilution for replacement of exchangeable sodium. Lagoon spentwash contained higher amount of calcium (1920 mg/l) than sodium (700 mg/l). Calcium being divalent which is present in effluent having higher replacing power has displaced sodium from exchangeable complex. This brings the reduction in exchangeable sodium content. The reduction in exchangeable sodium with effluent irrigation is in corroboration with report of Pawar *et al.* (1992).

Reduction in exchangeable sodium by gypsum amendments over control is due to supply of calcium with gypsum, which displaces sodium from exchange complex. The beneficial effect of pressmud is to supply calcium on decomposition and improvement in soil physical condition (Puttaswamy Gowda and Pratt, 1973).

The exchangeable potassium of soil treated with different levels of lagoon spentwash mixed river water and amendments shown in the Table 21 revealed that there was higher exchangeable potassium in surface layer than layers below. This higher exchangeable potassium in surface layer is due to the fact that adsorption of potassium by soil which is present in the effluent and more contact of potassium in surface layer.

Effluent irrigation of various dilution levels also resulted in increase in exchangeable potassium over control. In the interaction of depth and dilution level also higher accumulation of exchangeable potassium was found in I₁ dilution at D₁ depth followed by D₂ and D₃. It may be due to supply of potassium from effluent. Lagoon spentwash contained very high amount of total potassium (8700 mg/l). Hence, lower the dilution, more will be the accumulation of exchangeable potassium. Similar results were also reported by Pawar *et al.* (1992).

Among the amendments, pressmud was found to accumulate more of exchangeable potassium as compared to other amendments. Such an increase may be attributed to higher potassium content of pressmud (0.31 %). In dilution level X amendment interaction, higher quantity of exchangeable potassium was observed in I₁ dilution with pressmud amendment. Similarly, in three way interaction highest exchangeable potassium was noticed in I₁P treatment in all the three depths. Such an increase in exchangeable potassium may be attributed to presence of higher potassium concentration in effluent and mineralisation of pressmud.

The exchangeable calcium of soil (Table 22) leached with different levels of lagoon spentwash : river water resulted in higher exchangeable calcium at surface layer and it decreased with depth, indicating more opportunity time for adsorption at surface layer than subsurface. As the concentration of effluent added increases, more and more addition of calcium takes place which inturn helps for higher adsorption of calcium. Lagoon spentwash contained higher amounts of calcium (1920 mg/l) which might have resulted in higher accumulation of calcium. The present findings are in accordance with the report of Ramanathan *et al.* (1977) who noticed higher concentration of calcium in soils irrigated with sewage. Among the amendments significant increase in exchangeable calcium was noticed in pressmud plus gypsum

amendment. Soluble calcium in the media increased with the increase in solubility of gypsum in presence of pressmud might have resulted in more adsorption of calcium under pressmud and gypsum amendment. Increase in supply of soluble form of calcium from gypsum and pressmud is reported by Puttaswamy Gowda and Pratt (1973). Goldon (1975) and Prasad (1976) also reported increase in availability of calcium in soil due to filter pressmud application. The interaction of effluent and river water dilution and amendment on exchangeable calcium under I₁G+P is ascribed to the addition of calcium through effluent and soluble calcium from gypsum and pressmud. Gupta *et al.* (1987) observed higher content of calcium in pressmud application.

Lagoon spentwash mixed river water and amendment on exchangeable magnesium of soil was increased with depth indicating preferential adsorption of calcium over magnesium at surface layer from the media and subsequent increase in magnesium content of media might have resulted in increased accumulation of exchangeable magnesium at subsurface. The higher accumulation of exchangeable magnesium with higher dilution of effluent might be attributed to the preferential adsorption of magnesium over calcium. The reduction of exchangeable magnesium by spentwash application is in agreement with the findings of Pawar *et al.* (1992), Jadhav and Savant (1975).

Exchangeable magnesium content of soil under pressmud was higher than other two amendment treatments. The decrease in exchangeable magnesium under gypsum and gypsum plus pressmud may be due to lesser quantity of magnesium present in gypsum.

The higher soluble sodium content in soil under river water treatment over other effluent dilutions (Table 24) may be ascribed to the higher content of Na in river water than effluent dilutions. By and large, soluble sodium content was increased at higher dilution level of effluent : river water. It is evident that effluent itself carried higher quantity of sodium at lower dilution level.

Addition of pressmud increased soluble sodium content which might be due to the presence of sodium in pressmud (Puttaswamy Gowda and Pratt, 1973). Because of the above reason, in the interaction of depth and amendment, pressmud recorded higher soluble sodium than control. In the interaction of dilution and amendment, gypsum was found to be better in reducing soluble sodium even in I₁ effluent dilution level. Increase in soluble Na under interaction between amendment and effluent dilution is because of replacement of Na by Ca released from gypsum. And at higher dilution of effluent it is because of Krishna river water which contained higher amount of Na.

The soluble potassium of soil treated with different levels of lagoon spentwash mixed river water and amendments shown in Table 26 revealed that there was higher soluble potassium in surface layer than the layer below. This higher soluble potassium in surface layer is due to more detention time available for surface layer to adsorb more potassium from effluent. Effluent irrigation of various dilution level also resulted in increase in soluble potassium over control. In the interaction of depth and dilution level, higher accumulation of soluble potassium was found in I₁ dilution of D₁ depths followed by D₂ and D₃ depth. Lagoon spentwash contained very high amount of total potassium. Hence lower the dilution, more will be accumulation of soluble potassium in soil. Similar results were reported by Jadhav and Savant (1975). Among the amendments, pressmud was found to accumulate more of soluble potassium as compared to other amendments. Such an increase may be attributed to higher potassium content of pressmud. In the interaction of dilution and amendment, higher quantity of soluble potassium was found in I₁ dilution with pressmud amendment. Similarly in the three way interaction also higher soluble potassium was recorded in I₁ dilution in conjunction with pressmud at all the depths. Such an increase in soluble potassium may be attributed to higher potassium in effluent and mineralisation of K from pressmud.

Soil column leaching with different levels of lagoon spentwash mixed river water and amendments on soluble calcium plus magnesium (Table 27) showed that the soluble Ca + Mg content decreased as depth of soil column increased. The Ca + Mg adsorption is more at surface level causing lesser accumulation at subsurface. The higher accumulation of soluble Ca + Mg at lower effluent dilution level was noticed. It may be due to higher amount of Ca + Mg in lagoon spentwash at lower dilution of effluent. Higher content of soluble Ca + Mg in soil was observed with all the amendments over control. Higher accumulation of soluble Ca + Mg was found in G + P amendment. It is evident that Ca + Mg release will be more from gypsum in the presence of pressmud (Bhat, 1994).

The data on (table 27) effect of different levels of diluted lagoon spentwash with river water and amendments on soluble bicarbonate revealed that the soluble bicarbonate content increased with depth of soil column indicating mobility of bicarbonate from surface and accumulation at subsurface. By and large, at lower dilution level higher accumulation of soluble bicarbonate content in soil was observed. It is due to higher bicarbonate content of lagoon spentwash. It is in accordance with the findings of Jadhav and Savant (1975).

Among the amendments pressmud was found to contain higher quantity of soluble bicarbonate when compared to

other amendments. The higher accumulation of bicarbonate from pressmud may be due to higher evolution of carbon dioxide and its conversation into bicarbonates (Patel and Singh, 1991). The interaction of I X A , I X D, A X D and I X A X D showed similar trend.

Soil column leaching with different levels of lagoon spentwash with river water and amendments on soluble chloride (Table 28) revealed that the soluble chloride content increased with depth of soil column indicating mobility of chloride ion from surface and accumulation at subsurface. The lower dilution of effluent had higher content of soluble chloride. It is due to higher chloride content of lagoon spentwash. Similar trend was also noticed in respect of interaction of depth and dilution. It is in agreement with the report of Jadhav and Savant (1975) who reported that negative adsorption by the soil might be responsible for increased water soluble chloride content. Among the amendments, pressmud treatment increased the soluble chloride content of the soil. This may be due to presence of higher soluble chloride in pressmud. It is in corroboration with report of Shindhe (1993). The interaction between depth and amendment and dilution in respect of soluble chloride followed the same trend as that under individual effect.

The soluble sulphate content increased with depth of soil column indicating mobility of sulphate ions due to

negative charge from surface and accumulation at lower layers. Higher sulphate content in lower dilution of effluent : river water is due to higher sulphate content of lagoon spentwash. Similar trend was also noticed in the interaction of depth and dilution. Among the amendments, application of pressmud increased the soluble sulphate content of soil. This might be attributed to the higher sulphate content of pressmud when compared to other amendments.

SUMMARY

VI . SUMMARY

A field experiment was conducted during 1993-94 at Ugar Khurd, taluk Athani in Belgaum district to study the effect of diluted Ugar Sugar distillery effluent irrigation on soil properties, uptake of nutrients and yield. Soil column leaching study was also carried out to know the effect of 1:10, 1:25, 1:50 and 0:100 diluted distillery effluent irrigation on soil chemical properties in presence of pressmud, gypsum, gypsum + pressmud and unamended control. The results are summarized in the following paragraphs.

The pH of soils after the harvest of crops decreased due to effluent irrigation. Comparatively higher reduction in the pH of soils was observed in the soils irrigated with 1:10 effluent irrigation. Application of pressmud significantly decreased the pH of soils after the harvest of sugarcane, maize and wheat crops.

The organic carbon percentage and Ec of soils increased significantly due to diluted distillery effluent irrigation after the harvest of sugarcane, maize and wheat. Significant increase in Ec and OC of soils was also observed due to pressmud application.

The available N, P and K and exchangeable Na and Mg content increased significantly due to diluted distillery

effluent irrigation. The highest increase of these nutrients was noticed in 10 times effluent irrigated plots after the harvest of sugarcane, maize and wheat. Application of pressmud as an amendment increased all these nutrients compared to control (No amendment).

The exchangeable calcium content of soil was significantly higher in 1:10 effluent dilution plots when compared to 1:25, 1:50 and 0 : 100 effluent dilutions. Application of gypsum plus pressmud significantly increased the exchangeable calcium content compared to other amendments.

Increase in the grain yield of wheat was observed in 1:50 effluent dilution irrigated plots while the cane yield of sugarcane were significantly higher under 1:10 effluent dilution plots. Invariably the straw yield of all the three crops were significantly more in 1:10 effluent dilution plots. Grain and straw yields of all the three crops were higher with pressmud amendment.

The uptake of nutrients such as N, P, K, Ca and Mg increased under 1:10 effluent irrigation when compared to irrigation with 25 and 50 times effluent dilution. Increase in uptake of N, P, K, Ca and Mg by wheat, maize and sugarcane was also higher under pressmud application as an amendment.

The pH of soil column was found to increase with depth. The decrease in pH with lower effluent river water ratio was from 8.22 to 7.86. Among the amendments pressmud was found to reduce the pH of the soil.,

The EC of the soil was not affected by leaching of the soil column with different dilutions of distillery effluent. Application of pressmud was found to increase the EC from 0.60 to 0.63 dSm⁻¹ (control).

The exchangeable sodium content of the soil increased with depth. A reduction of exchangeable sodium from 3.66 cmol (p⁺) kg⁻¹ under Krishna river water to 1.66 cmol (p⁺) kg⁻¹ under 1:10 effluent : river water dilution was observed. Among the amendments pressmud plus gypsum was found to be better in reducing exchangeable sodium content of the soil.

Both exchangeable and soluble potassium content of the soil decreased with depth irrespective of effluent dilution levels and amendments. Lower effluent dilution resulted in higher accumulation of both exchangeable and soluble potassium. Increase in exchangeable as well as soluble potassium was recorded pressmud amendment.

Higher levels of effluent dilution resulted in lower exchangeable calcium content of soil. Increase in exchangeable calcium was highest with pressmud plus gypsum amendment. The

exchangeable magnesium content significantly increased with depth. Higher level of effluent dilution recorded significantly higher exchangeable magnesium content. The pressmud application was found to increase the exchangeable magnesium content. The increase soluble sodium content under 0:100 effluent dilution was highest and increase was from 2.68 (under 1:10 effluent dilution) to 3.45 me L^{-1} (under river water). Application of pressmud increased the soluble sodium content of soil.

Higher level of effluent dilution significantly decreased the soluble Ca + Mg content. The soluble anion content of soil generally increased with depth. By and large, lower dilution level, increased the soluble anion content of the soil. The reduction in soluble bicarbonate, chloride and sulphate due to amendments was in the order of pressmud > gypsum + pressmud > gypsum > control.

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Per cent nutrient uptake by sugarcane, maize and wheat due to distillery effluent irrigation

contd.

Contd...

E:K	C	G	G+P	P	C	G	G+P	P	C	G	G+P	P
1:50												
Grain	--	--	--	--	0.19	0.19	0.19	0.19	0.05	0.06	0.08	0.10
Straw	0.02	0.02	0.02	0.02	0.09	0.09	0.09	0.10	0.27	0.26	0.26	0.26
0:100												
Grain	--	--	--	--	0.16	0.16	0.16	0.16	0.03	0.04	0.06	0.08
Straw	0.02	0.02	0.02	0.02	0.06	0.06	0.07	0.07	0.24	0.24	0.23	0.16
Potassium												
1:10												
Grain	--	--	--	--	0.26	0.28	0.29	0.30	0.38	0.42	0.46	0.50
Straw	0.18	0.18	0.18	0.18	0.93	0.94	0.92	0.93	1.18	1.16	1.12	1.08
1:25												
Grain	--	--	--	--	0.30	0.32	0.32	0.32	0.36	0.40	0.42	0.43
Straw	0.18	0.18	0.18	0.18	0.91	0.93	0.91	0.90	1.04	1.02	1.00	0.98
1:50												
Grain	--	--	--	--	0.32	0.35	0.37	0.33	0.30	0.35	0.39	0.41
Straw	0.18	0.18	0.18	0.18	0.95	0.93	0.92	0.91	0.96	0.95	0.94	0.93
0:100												
Grain	--	--	--	--	0.29	0.31	0.33	0.33	0.28	0.30	0.32	0.34
Straw	0.18	0.18	0.18	0.18	0.83	0.89	0.88	0.87	0.93	0.92	0.92	0.91
Calcium												
1:10												
Grain	--	--	--	--	0.10	0.12	0.12	0.13	0.40	0.45	0.48	0.52
Straw	0.17	0.18	0.17	0.15	0.13	0.14	0.14	0.15	0.92	0.90	0.89	0.87

Contd....

E:K	C	G	G+P	P	C	G	G+P	P	C	G	G+P	P
1:25												
Grain	--	--	--	--	0.10	0.12	0.13	0.14	0.35	0.43	0.47	0.50
Straw	0.18	0.19	0.19	0.18	0.12	0.13	0.13	0.14	0.86	0.84	0.82	0.80
1:50												
Grain	--	--	--	--	0.11	0.12	0.13	0.13	0.37	0.41	0.45	0.49
Straw	0.19	0.19	0.19	0.19	0.13	0.13	0.15	0.15	0.78	0.76	0.74	0.72
0:100												
Grain	--	--	--	--	0.11	0.13	0.13	0.13	0.35	0.39	0.43	0.48
Straw	0.18	0.19	0.19	0.19	0.13	0.14	0.14	0.14	0.70	0.70	0.69	0.68

Magnesium

1:10												
Grain	--	--	--	--	0.05	0.07	0.07	0.08	0.28	0.29	0.30	0.32
Straw	0.05	0.07	0.07	0.08	0.09	0.09	0.10	0.11	0.52	0.50	0.49	0.49
1:25												
Grain	--	--	--	--	0.05	0.06	0.07	0.08	0.27	0.28	0.29	0.31
Straw	0.04	0.06	0.07	0.07	0.09	0.09	0.10	0.11	0.48	0.46	0.43	0.42
1:50												
Grain	--	--	--	--	0.05	0.06	0.08	0.09	0.26	0.27	0.28	0.28
Straw	0.04	0.05	0.07	0.07	0.09	0.10	0.11	0.11	0.46	0.39	0.38	0.36
0:100												
Grain	--	--	--	--	0.05	0.07	0.09	0.09	0.25	0.27	0.27	0.27
Straw	0.04	0.05	0.06	0.07	0.09	0.09	0.10	0.10	0.36	0.35	0.34	0.34

APPENDIX-II

Composition of Ugar sugar factory distillery effluent at different points and Krishna river water.

Sl.No	Parameters	Root spent wash	Lagoon spent wash	diluted lagoon spent wash	Effluent before entering the field	Krishna river water
1.	Colour	Reddish brown	Dark brown	Light brown	Light brown	Clear
2.	Odour	unpleasant smell of burnt sugar	unpleasant smell	Tolerable	Tolerable	No odour
3.	Temperature (°C)	90-95	30.00	28-30	28-30	28-30
4.	pH	4.03	7.62	7.05	7.04	7.80
5.	EC (ds m ⁻¹)	12	17.00	1.20	1.10	0.60
6.	Total solids (mg/l)	35,490	25,832	1920	1704	960
7.	total dissolved solids	18,050	18,932	1064	940	662
8.	Total suspended solids	17890	6900	856	764	298
9.	BOD sd (mg/l) (5 days)	40,000	6000	280	140	ND+
10.	COD (mg/l)	1,14000	34,400	412	368	ND+
11.	Total nitrogen (mg/l)	1,470	800	20	7.60	traces
12.	Total phosphorus (mg/l)	915	317	13	11.0	traces
13.	Potassium (mg/l)	8900	8700	150	100	1.00
14.	Sodium (mg/l)	880	700	72	68	55
15.	Calcium (mg/l)	2240	1920	160	150	33.40
16.	Magnesium (mg/l)	1296	828	60	54	60.0
17.	Carbonates (mg/l)	Nil	Nil	NIL	Nil	Nil
18.	Bicarbonates (mg/l)	13322.40	14432.6	3050	277.55	138.78
19.	Chlorides (mg/l)	5020	2800	852	355	177.50
20.	Sulphate (mg/l)	1900	1980	45	38.64	2.88
21.	Iron (mg/l)	58.56	27.49	4.50	3.88	2.55
22.	Manganese (mg/l)	5.20	1.80	0.80	0.88	0.40
23.	Copper (mg/l)	4.00	2.32	0.68	0.22	0.16
24.	Zinc (mg/l)	6.52	2.94	1.12	1.12	0.53

+ - Not detected

APPENDIX-III

Composition of pressmud

Sl. No.	Parameter	
1.	pH (1:2.5 ratio)	6.15
2.	EC (dsm^{-1}) (1:2.5 ratio)	5.20
3.	Nitrogen (%)	0.57
4.	Phosphorus (%)	1.10
5.	Potassium (%)	0.45
6.	Calcium (%)	4.20
7.	Magnesium (%)	0.54
8.	Sulphate (%)	1.07
9.	Iron (ppm)	5500.00
10.	Mangeneses (ppm)	377.00
11.	Zinc (ppm)	935.00
12.	Copper (ppm)	187.00
13.	Chlorides (%)	0.15
14.	Sodium (%)	0.19
15.	Organic carbon (%)	39.40
16.	C:N ratio	69.13

APPENDIX-IV

Monthly Rainfall and mean, maximum and minimum temperature recorded at Ugarkhurd, taluk Athani during 1993-94

Months	Rainfall (mm)	Mean temperature (°C)	
		Maximum	Minimum
July, 1993	69.00	29.21	22.10
August, 1993	70.80	28.65	21.71
September 1993	72.50	29.97	20.81
October 1993	99.25	31.00	21.55
November 1993	--	30.80	18.27
December 1993	19.00	27.39	15.29
January, 1994	10.50	30.98	16.35
February, 1994	--	32.96	16.71
March, 1994	--	38.32	20.48
April, 1994	23.00	36.58	22.00
May, 1994	75.20	--	--

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ಗಾ.ಕೆ.ವಿ.ಸಿ., ಬೆಂಗಳೂರು-65
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