IMPACT OF INDUSTRIAL LIQUID AND SOLID WASTE ON CROP GROWTH, NUTRIENT ABSORPTION AND SOIL PROPERTIES

BY

H. V. MATHAKIYA

M. Sc. (Agri.)

DEPARTMENT OF AGRIL. CHEMISTRY AND SOIL SCIENCE

N. M. COLLEGE OF AGRICULTURE

GUJARAT AGRICULTURAL UNIVERSITY

NAVSARI CAMPUS, NAVSARI - 396 450

GUJARAT STATE

MAY-2002

- 3987 - 97

DEDICATED TO MY BELOVED LATE FATHER

IMPACT OF INDUSTRIAL LIQUID AND SOLID WASTE ON CROP GROWTH, NUTRIENT ABSORPTION AND SOIL PROPERTIES

A

THESIS

SUBMITTED TO THE

GUJARAT AGRICULTURAL UNIVERSITY

SARDAR KRUSHINAGAR

IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR

THE AWARD OF THE DEGREE

OF

DOCTOR OF PHILOSOPHY

IN

AGRIL. CHEMISTRY AND SOIL SCIENCE

BY

H. V. MATHAKIYA
M. Sc. (Agri.)

DEPARTMENT OF AGRIL. CHEMISTRY AND SOIL SCIENCE
N. M. COLLEGE OF AGRICULTURE
GUJARAT AGRICULTURAL UNIVERSITY
NAVSARI CAMPUS, NAVSARI - 396 450
GUJARAT STATE

MAY-2002

Registration No. 04 - 3987 - 97

ABBREVIATIONS USED

BC	Biocompost
BS	Biological sludge
Ca	Calcium
Ca CO_3	Calcium carbonate
Cd	Cadmium
C.D.	Critical difference
CEC	Cation exchange capacity
Cl^-	Chloride
cm	Centimeter
Co	Cobalt
CO_3^{-2}	Carbonate
CRD	Complete randomized design
Cu	Copper
dSm^{-1}	Deci Siemens per meter
DTPA	Diethyline triamine penta acetic acid
EC	Electrical conductivity
Fe	Iron
Fig.	Figure
FYM	Farm yard manure
g cm^{-3}	Gramme per cubic centimeter
g ha^{-1}	Gramme per hectare
g kg^{-1}	Gramme per kilogram
g pot^{-1}	Gramme per pot
HCO_3^-	Bicarbonate
IS	Indian standards
K	Potassium
KCl	Potassium chloride
kg ha^{-1}	Kilogram per hectare
K_2O	Potassium oxide
L m^{-2}	Liter per square meter
m	Meter
m^2	Square meter
mcm	Million cubic meter
me l^-	Milliequivalent per liter
Mg	Magnesium
mg	Milligram
Mg ha^{-1}	Megagram per hectare
mg l^{-1}	Milligram per liter
mg kg^{-1}	Milligram per kilogram
Mg m^{-3}	Megagram per cubic meter
mm wk^{-1}	Millimeter per week

mg pot $^{-1}$	Milligram per pot
Mn	Manganese
m^2	Square meter
m^3 ha^{-1}	Cubic meter per hectare
N	Nitrogen
Na	Sodium
ND	Not detectable
Ni	Nickel
NS	Non-significant
O.C	Organic carbon
P	Phosphorus
Pb	Lead
pH	Negative logarithm of hydrogen ion activity
PM	Pressmud
P_2O_5	Phosphorus pentoxide
ppm	Parts per million
RDF	Recommended dose of fertilizer
RIL	Rallies India Ltd.
SAR	Sodium adsorption ratio
S.Em.	Standard error of mean
S	Sulphur
SO_4^{-2}	Sulphate
Sr. No.	Serial number
T	Treatment
t ha^{-1}	Tonne per hectare
UPL	United Phosphorus Ltd.
-ve	Negative
yrs	Years
Zn	Zinc
%	Per cent
@	At the rate of

ABSTRACT

Impact of industrial liquid and solid waste on crop growth, nutrient absorption and soil properties.

Student :
H.V.Mathakiya

Major Advisor
Dr. M.B.Meisheri

Department of Agricultural Chemistry and Soil Science
N.M.College of Agriculture,
Gujarat Agricultural University,
Navsari Campus, Navsari-396450.

ABSTRACT

The present study for evaluating the feasibility of using industrial wastes in different crops was taken up on Typic Chromustert soil of Navsari during *rabi* (1999) and *summer* (2000) seasons in two phases. In first phase, the first pot experiment was carried out to study the impact of diluted effluents water (RIL and UPL effluent) on onion (*Allium cepa*.L.) crop (Direct effect) to find out the feasibility of curtailing fertilizer use when irrigated with diluted effluents water. The second pot experiment was carried out in the same pots of first experiment subsequently after first experiment to study the cumulative effect of diluted effluents water on growth of fodder maize (*Zea mays*) crop. The results indicated that 50 per cent recommended dose of fertilizer nutrients could be saved in both the cases i.e. direct as well as cumulative effect due to increase in fertilizer use efficiency.

The content and uptake of major (N, P and K), secondary (Ca, Mg and S) and micronutrients (Fe, Mn, Zn and Cu) were recorded higher under both the effluent irrigation treatments as compared to canal water irrigation. The heavy

metals concentration (Pb, Cd, Ni and Co) in plant tissue was of lower limits. The concentration of such metals remained below critical phytotoxic limits in both direct and cumulative effect. In case of soil properties, the results did not indicate deleterious effect due to both effluent irrigation as compared to normal water irrigation. The available nitrogen status and electrical conductivity of soil and the nutrient element like P, K, Fe, Mn, Zn and Cu were increased significantly under effluents irrigation. DTPA extractable heavy metal like Ni and Co was slightly increased but remained within permissible limits.

As a second part of the study, two field experiments were conducted wherein, the relative performance of different industrial solid wastes such as biological sludge @ 2.5 t $ha^{-1}$and @ 5 t ha^{-1}, pressmud @ 5 t ha^{-1}, biocompost @ 5 t ha^{-1} and FYM @ 5 t ha^{-1} alongwith full and half recommended doses of fertilizers and one control (100 per cent RDF only) were evaluated on cabbage (*Brassica oleracea Var.Capitata*) crop as a direct effect and on summer groundnut (*Arachis hypogea*) crop as a residual effect in four replication of RBD design. The results revealed that direct application of organic industrial waste could save half the recommended doses of fertilizers. Among the different solid wastes, application of biological sludge @ 5 t ha^{-1} performed significantly better than the rest of the materials used, in case of head and stump (Unwrapped leaves + stem) yield of cabbage (25.91 and 24.09 t ha^{-1}, fresh head and stump) followed by FYM, biocompost and pressmud in decreasing order. Besides, application of all the wastes alongwith 50 per cent RDF practically remained same with 100 per cent recommended doses of inorganic fertilizer only. The major (N, P and K), secondary (Ca, Mg, S) and micro (Fe, Mn, Zn, Cu) nutrient content in plant tissue and their uptake by cabbage crop were remarkably higher under application of different industrial wastes alongwith 100 per cent RDF, as compared to control. The concentration of heavy metals (Pb, Cd, Ni and Co) in plant parts were below the phytotoxic limits. Among the different soil properties, pH remained unaffected. Organic carbon and electrical conductivity status of the soil was slightly increased. Available major (N, P, K) and micro nutrients (Fe, Mn, Zn and Cu) were increased under application of solid wastes materials as compared to control treatment. The heavy metals (Pb, Cd, Ni and Co) concentration in soil was found non-significant.

In case of residual effect, though the pod yield of groundnut under industrial waste treatment recorded higher as compared to control but was found non- significant. However, haulm yield showed good performance under solid waste application as compared to control. Maximum haulm yield was recorded under pressmud application (9340 kg ha^{-1}) followed by biological sludge @ 5 t ha^{-1} treatment (9265 kg ha^{-1}). All the major and micronutrients uptakes were higher under waste material application treatments both in pod and haulm except N and Mg in pod. While micronutrient (Fe, Mn, Zn and Cu) uptakes by pod was not significantly affected but in haulm which were higher under waste material application treatments. The concentration of heavy metals (Pb, Cd, Ni and Co) in both plant parts were below the phytotoxic limits. Among the different soil properties, EC was slightly increased where as pH and organic carbon status was not changed. Available N, P_2O_5 and K_2O were marginally increased. The available Fe and Zn were increased but Mn and Cu remained unchanged. Heavy metal concentration in soil was also not significantly affected as like the direct effect.

Bulk density and water stable aggregate > 0.25 mm after harvest of groundnut was not significantly affected.

Dr. M. B. Meisheri
Associate Director of Research(Zone),
Gujarat Agricultural University,
Navsari Campus,
Navsari-396450.

CERTIFICATE

This is to certify that the thesis entitled "IMPACT OF INDUSTRIAL LIQUID AND SOLID WASTE ON CROP GROWTH, NUTRIENT ABSORPTION AND SOIL PROPERTIES" submitted by Shri HUSHENMAMAD VALIBHAI MATHAKIYA, in partial fulfil ment of the requirements for the degree of DOCTOR OF PHILOSOPHY (Agriculture) in Agricultural Chemistry and Soil Science of the Gujarat Agricultural University is a record of bonafide research work carried out by him under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place : Navsari

Date : 13th May, 2002

(M. B. Meisheri)

MAJOR ADVISOR

DECLARATION

This is to declare that the whole of the research work reported here in the thesis for the partial fulfil ment of the requirements for the degree of DOCTOR OF PHILOSOPHY (Agriculture) in Agricultural Chemistry and Soil Science by the undersigned is the result of investigations done by him under the direct guidance and supervision of Dr. M. B. Meisheri, Associate Director of Research (Zone), Gujarat agricultural University, Navsari and no part of the work has been submitted for any other degree so far.

Place : Navsari

Date : 13th/5/2002

(H. V. Mathakiya)

Countersigned by

(M. B. Meisheri)

Associate Director of Research (Zone)

Gujarat Agricultural University

Navsari.

ACKNOWLEDGEMENT

I have both pleasure and privilege in expressing my heartiest gratitude to my major advisor, Dr. M.B. Meisheri, Associate Director of Research (Zone), Gujarat Agricultural University, Navsari for his valuable guidance, constructive criticisms, constant encouragement and help during the course of present investigation and preparation of this document.

My cardial thanks are also due to the members of my Advisory Committee, Dr. C.L. Patel, Research Scientist, AICRP on Sugarcane, Dr. R.R. Kaswala, Professor and Head, Agril. Chemistry and Soil Science and Dr. R.K. Parikh, I/C Professor, Dept. of Agril. Statistics, N.M. College of Agriculture, G.A.U., Navsari for their valuable and constructive suggestions during the course of this study.

I am grateful to Principal, N.M. College of Agriculture, Navsari for providing necessary facilities during the period of research work.

My special appreciation goes to Dr. S. Raman, Research Scientist, Soil and Water Management project, Navsari for providing necessary facilities for conducting pot and field studies.

Special thanks are also due to Dr. N.M. Zalawadia, Dr. R.G. Patil, Dr. A.M. Patel, Shri. R.C. Gami as well as other staff members of Agril. Chemistry and Soil Science Dept., N.M. College of Agriculture, Navsari for valuable help and inspiration during the course of my study.

I am thankful to Mr. M.G. Surma, Mr. S.M. Patel, Mr. C.V. Chaudhri and other Staff members of Soil and Water Management Project for their kind help and co-operation. The timely help rendered for micro-nutrient and heavy metal determination by Dr. K.P. Patel and his staff, Micro-nutrient Project, G.A.U., Anand is also gratefully acknowledged.

I express my heartfelt thanks to Dr. A. Das, Associate Research Scientist, Regional Research Station, Arnej for his help with smil ing face during preparation of this manuscript and Mr. M.D. Vora in computer work.

I wish to put on record my heartiest thanks to my colleagues and friends sarvashri, Mustafa Malik, Anand Kaswala, Sanjay Pawar, Bharat Vekariya, Hiren Surma, Vikash Deshmukh and Mr. M.K. Malik whose unfailing support has greatly helped me in the completion of this study.

I extend my sincere regards to my beloved father, mother, brothers who have always been source of incessant inspiration to me.

Last but not least, my wife Mrs. Ayesha, Son Sabbir deserve special appreciation and compliments for their personal sacrifice, moral support and constant encouragement during the completion of this venture.

Place : Navsari

Date : 13th May, 2002

(H.V. Mathakiya)

CONTENTS

LIST OF TABLES

TABLE NO.	TITLE	PAGE NO.

LIST OF FIGURES

INTRODUCTION

INTRODUCTION

The current aim of sustainable agriculture is to develop farming systems that are productive and profitable, conserve natural resources base, protect the environment and enhance health and safety in long term prospective. Low input farming system seeks to minimize the use of external inputs like fertilizers and avoid pollution of surface and ground water and lower the production cost.

In the wake of technological advancement and with the increasing trend in industrialization and urbanization there is tremendous increase in the production of industrial effluent and solid waste materials and as a consequence waste accumulation has enhanced and its disposal has assumed a serious dimensions not only in the western world but also in the third world. Waste may be of solid, liquid and gaseous phases. Different kinds of wastes including domestic wastes, city garbages, sewage effluents and sludges, vegetable wastes, crop residues, industrial effluents and sludges etc. affect the environment and the harmonious relationship between the biotic and abiotic components of the ecosystem.

To minimize the harmful effect of such wastes on land, soil-water-climate and on overall environment, recycling, reprocessing of wastes from different sources and \ or putting them to productive use is a must. Limited availability of fossil fuel and energy crisis are of great concern world wide and every country is now exploring the possibilities of utilizing all the available resources not only to overcome the energy crisis but also for getting sustainable soil productivity.

Out of 1551 industries in the country 166 were identified as the highly polluting industries. A huge volume (66 mcm \ annum) of industrial effluents are given out (Juvarkar *et al.,* 1992) in India. Effluents \ Wastes, being as whole toxic and pollutant, are required to be disposed of safely. Because of their inherent ability to pollute the environment, unscientific disposal poses a very serious problem to soil and water. With the increasing number of agro-chemical industries such problem of disposal of wastes \ effluent has increased many fold and has become a threat to the environment. However, the quality of industrial waste \ effluents depends upon the raw material used and the products and by-product produced. Industry wise considerable variation in the composition of effluent (Bahirat *et al.*, 1989 and Palaniswami and Ramula, 1994) as well as solid waste (Bhagavati and Durai, 1996 and Raman *et al.*, 1996) has been reported. Though most of the industrial wastes \ byproducts may act as pollutant, yet some of them may be used profitably in agriculture provided they are used scientifically and judiciously. There are some industrial wastes \ effluents containing nutrient elements, manurial and ameliorative elements in appreciable quantities necessitating their application in agriculture. Development of suitable technologies to utilize these resources need much attention.

Many byproducts obtained from factory \ industry have good potential for their suitable use in agriculture. Byproducts like phosphogypsum are already being used as an agent for ameliorating salt affected soils. It is already mentioned that industrial solid wastes have good manurial and reclaimant value. Some biosludge obtained from wastewater by treating suitable bioagents are rich in organic carbon and others major and micronutrients have good potential to use in agriculture. Carbonated pressmud or sulphonated pressmud which are obtained as a byproduct in sugar industry contain high amount of organic carbon, nutrients like N, P, K, Ca, S and other micro nutrients (Abubacker and Rao, 1995), has tremendous potential to improve yield of crop. Biocompost, a humus-rich organic manure from waste which is prepared by mixing pressmud and distillery effluent in the ratio of 1:2.5 (Ramaswami, 1999) with the aid of bacterial culture has potential to use in agriculture as a manure. Efforts have been made by many workers (Raman *et al.*, 1996; Dang and Verma, 1996; Tiwari *et al.*, 1998; Sawarkar and Dikshit, 1990 and Sarkunan *et al.*, 1993) for using pressmud and other industrial wastes for partial substitution of inorganic fertilizer for improving soil productivity. Patel and Singh (1991) tried it as a reclaimant in place of gypsum and found that application of pressmud @ 50 per cent of gypsum requirement increased the dry matter production of rice and wheat.

Considering the ever increasing demand for irrigation water some workers (Ajmal and Khan, 1983; Pande *et al.*,1990; Yaduvanshi and Yadav, 1996) have tried to use the industrial effluent profitably in agriculture giving due consideration to the quality and quantity of effluent, soil type and crop. Sewage from Ahmedabad, an important center of textile industries, has been successfully utilized in growing valuable crops without having any ill effect on irrigated lands, even though the sewage contains about 30 per cent industrial waste mainly from textile industries (Mahida, 1981). Hence, there is need to properly assess the pollution load in different industrial effluents \ wastes and their scope for being utilized profitably. Direct use of wastewater in high concentration should be avoided for its re-use in agriculture (Ranwa, 1999). Inspite of its pollution hazard, effluents can be regarded as dilute, liquid organic material with fertilizer value. Efforts have been made by many workers (Bahirat *et al.*,1989; Malti *et al.*,1998; Neelam and Sahai, 1988 and Traka *et al.*,1998) for using such effluents for partial substitution of inorganic fertilizer and improving soil productivity. Therefore, it is necessary to understand in depth, the effect of addition of effluents on soil properties and yield and chemical composition of crops.

Solid and liquid waste materials, if disposed of on land or in the river it will result in polluting the land, water and atmosphere. All such waste materials are to be processed systematically and scientifically and utilized profitably in agriculture.

At present use of chemical fertilizers in agriculture is increasing day by day, but the production of commercial fertilizer is not increasing to meet its demand. Further, with the removal of subsidies, fertilizers have become considerably costlier. Since, agrochemical effluent is rich in nitrogen and solid wastes rich in organic carbon, nitrogen, phosphorus and potassium and other macro and micro nutrients required for plants, it can be profitably utilized either as irrigation water (effluents) or as a manure (solid wastes) to supply nutrients to different crops. Though some research studies have been done in India and abroad throwing considerable light on various aspects of the utilization of industry effluent and solid wastes, yet information is lacking on the use of effluent for irrigation purpose and solid wastes as a manurial and the prospects of the possible reduction in the fertilizer use for different crops. Considering the above views, it was thought worthwhile to undertake the present investigation with the following objectives. :

i) to assess the quality of effluent water and solid waste collected from Rallis India Ltd., United Phosphorus Ltd., Cynamide India Ltd. and Chalthan Sugar factory,

ii) to investigate the feasibility of usage of effluent and solid waste,

iii) to explore the possibility of saving N, P and K fertilizer through use of effluent and solid waste,

iv) to study the dry matter production and uptake of nutrients by different crops,

v) to know the residual effect of solid waste and cumulative effect of effluent water on different crops,

v) to monitor the soil chemical and physical changes due to effluent and solid waste.

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

With linear increasing trend in industrialization and urbanization, there is tremendous increase in the production of industrial effluents and solid wastes, resulting in many times as source of soil and water pollution. Though, most of the industrial wastes (byproduct) may act as pollutant; yet some of them may be used in agriculture profitably, provided they are used scientifically and judiciously. At present, the wastes are disposed of through open surface water and land system taking it for granted that land is a neglected waste store. The quality of the effluent / solid waste affect the soil productivity, depending upon the nature of the effluent/solid waste, the quantity used and the soil parameters. Further, the local climatic conditions also affect the residual pollution in the soil. Keeping the above in view an attempt is made in this chapter to review the work done on some of the important aspects of effluent water/solid waste and their utilization for irrigation and manurial purposes, their response to the crop and effect on soil properties.

2.1 Effect of effluent water on crop growth, nutrient accumulation and quality

The response of a plant to liquid pollutant is an integration of the effects of many factors such as soil type, climate and nature of pollutant.

Larson *et al.* (1975) reported that industrial organic wastes could be used safely and effectively with proper precautions to increase soil productivity.

2.1.1 Direct effect of effluent water

2.1.1.1 Distillery effluent (spent wash)

With a view to studying the utility of spent wash (distillery effluent) for its manurial value, an experiment under field condition was conducted by Bajpai and Dua (1972) at Rampur Sugar factory farm where in they used twenty times diluted spent wash on N basis so as to supply 100, 200 and 300 kg N ha^{-1} and they found an increase in sugarcane yield up to the dose of 200 kg N ha^{-1}, but the higher doses affected cane yields adversely. They also noticed that the application of spent wash did not affect cane juice quality up to 200 kg N ha^{-1}. While in Philippines, Gonzales and Tinaco (1982) applied spent wash to sugar cane @ 83, 166 and 249 t ha^{-1} in addition to the regular fertilizer. They observed increase in cane yields over control by 12.3, 10.4 and 10.4 % and sugar yield by 15.4, 13.4 and 16.8 per cent, respectively. Ajmal and Khan (1983) studied the effect of sugar factory effluent on *Vigna radiata* and pearlmillet in Uttar Pradesh and 25 % of effluent water substitution was reported to be good for irrigation.

In laboratory experiments, the effects of 0, 1.0, 2.5, 5.0, 15, 30, 50, 75 and 100% distillery effluent solutions on germination and growth of *Vigna radiata* were studied by Sahai *et al.* (1985). They observed that the germination with 0 to 5, 15, 30, 50 and 75% effluent water was 98 to 100, 80, 64, 38 and 18 %, respectively. Increased effluent concentration reduced the earliness of germination. Treatments up to 5 % effluent increased root and shoot length, plant biomass, chlorophyll content and seed out put compared to the control. Above 5 % effluent concentration all values decreased. Mukherjee and Sahai (1988) observed that in *C. cajan* the rates and percentage germination and root length were maximum with the use of 5 % effluent, while shoot length was maximum due to 2.5% effluent concentration.

The lower concentration of distillery effluent increased seed germination and early seedling growth in cowpea, rice and sorghum while higher concentration retarded not only seed germination but also early seedling growth (Rajaram and Janaradhanan, 1988). On the other hand in soybean the percentage germination and early seedling growth were markedly suppressed. Zalawadia and Raman (1994) conducted a green house trial to study the effect of diluted distillery waste water in sorghum crop grown on a clayey Typic Chromurstert soil. They indicated that 75 % of the recommended fertilizer application and irrigating with distillery waste water, produced the yield which was at par with 100 % recommended dose of fertilizer application with normal water irrigation. The percent utilization of applied N, P and K though were more in distillery waste water irrigation with 75 % fertilizer dose than with normal water irrigation with 100 % fertilizer dose.

Devarajan and Oblisami (1995) conducted a field trial on a loamy sand soil (Inceptisol) at Sakthi Nagar, Tamil Nadu on sugarcane CV. Co-853 irrigated with distillery effluent diluted 10 to 50 fold and compared with water (control). Irrigation with 50- fold dilution gave the highest cane yield of 182.8 t ha^{-1} as compared with to control (159.5 t ha^{-1}). The cane yield decreased with increasing concentration of the effluent in the irrigation water, but the yield was significantly decreased at 10-fold dilution (149 t ha^{-1}). Juice quality also decreased by with increasing concentration of effluent in irrigation water.

2.1.1.2 Dairy effluent

Zabek (1976) working in light soils observed that irrigation with dairy effluent increased the N, P and K contents of root crops, green fodder, wheat grain and rapseed by 1.5 and 2 times. But it decreased the Ca and to some extent the Mg, Cu, Ni and Mo contents particularly in root crops. Dmitrieva *et al.* (1979) observed that the irrigation of pastures with dairy effluent at 30-120 mm (containing 295-1200 kg N, 167-200 kg P_2O_5 and 90-900 kg K_20 ha^{-1}) resulted in considerable increase in the green and dry herbage yields *visa a visa* irrigating with normal water along with application of mineral fertilizers. The dairy effluents increased the contents of Ca, Mg, P and K in the plant.

A series of experiments were carried out by Jenson (1981a) from 1971 to 1978 in which dairy waste water was applied to a number of crops on sandy soils and compared with non-irrigated, non-nitrogen fertilized plots. Application of 360 mm of dairy waste water increased yield of cereals by 75 %, grass and clover grass mixture by 67 % and root crops by 46 %. Ajmal *et al.* (1984) observed that the plant height was reduced by the use of dairy processing effluent (100 %). But, 25 % or 75 % effluent resulted in increased plant height in kidney bean and pearl millet.

Gautam and Bishnoi (1990) reported that germination of wheat seed with undiluted and diluted (1:1) dairy effluents and tap water was 96, 96 and 92 %, respectively. The diluted effluent was most effective in increasing growth and biomass production, followed by tap water and undiluted effluent in that order.

2.1.1.3 **Papermill effluent**

Rajannan and Oblisami (1978) observed a reduction in germination and growth of rice, blackgram and tomato crops with the use of papermill effluent, when used directly. But, the diluted effluent enhanced the growth of these crops.

Chaudhari *et al.* (1987) reported the germination percentage and seedling growth of maize seeds to increase with the effluent concentration of up to 25% and decreased at the higher concentration. It was suggested that papermill effluent after proper dilution (25 %) can be used for irrigation to maize crop. Fazeli *et al.* (1991) reported that the concentration of Cu, Pb, Zn, Ni, Co and Cd in coconut water, root and leaf were above the permissible limits when irrigated by papermill waste water. On the other hand Malti *et al.* (1998) observed the possibility of the use of diluted papermill effluent (1:1) for irrigating rice crop without any adverse effect on the growth and yield of rice.

2.1.1.4 Fertilizer and chemical factory effluents

The effect of pollution by effluent from a chemical and fertilizer factory on several growth parameters on wheat crop was investigated by Tripathi and Ambasht (1981) on four sites [I II III and IV (control) affected by decreasing pollution levels]. They showed an inversely proportional and significant relationship between the growth parameters and levels of pollution. Although the length of shoot and number of tillers in case of least polluted habitat (site III), were slightly higher than that of control habitat there was a sharp reduction in shoot length (37 %) and number of tillers (39-60 %) at moderate and highly polluted habitats (site II and site I). The number of leaves and stem diameter of wheat plant was reduced considerably at the polluted habitats. There was 35 to 45% decrease in the average length of ears at heavily and moderately polluted site. The overall growth performances of plants on sites I and II was very poor and on site III it was slightly less than that of the control plants (site IV).

Striban *et al.* (1986) studied the effect of chemical fertilizer factory effluent containing 84-308 kg N ha^{-1} on potatoes. The commercial tuber yields increased with N rates up to 252 kg ha^{-1} applied through the effluent water.

Neelam and Sahai (1988) investigated the impact of various concentration [viz., 1, 2.5, 5,10, 15, 30,50, 75 and 100 %)] of fertilizer factory effluent on seedling growth, pigment content and biomass of sesamum (*Sesamum indicum* Linn) and indicated that values of germination percentage and speed of germination index increased with an increase in the effluent concentration up to 5 % and decreased thereafter. The length of radicles, seedling biomass and pigment content increased when the plants were treated with up to 10% effluent, then decreased. The carotenoid content, however, increased with effluent concentration up to 30 %. Fertilizer factory effluent, normally highly toxic to plants, may be used for irrigation after dilution to 10 % of the original concentration.

To evaluate agricultural usefulness of a byproduct containing ammonium sulphate and ammonium nitrate obtained during simultaneous desulphurization and denitrogenization of power station flue gases as a fertilizer; a pot experiment was set-up with maize crop by Niedzwiecki *et al.* (2000). The equivalent of 0.3, 0.9 and 2.7 g N pot^{-1} was supplied as the byproduct, ammonium sulphate or ammonium nitrate or no fertilizer was applied. N application significantly increased the content of total N in the upper parts of the maize and its roots. The by-product was recommended as a useful N fertilizer for maize.

2.1.1.5 Tannery effluent

Pande *et al.* (1990) studied the effect of tannery effluent applied to sugarcane field in graded concentration viz., 0.0, 8.75, 17.5, 35.0, 70.0 and 140 m^3 ha^{-1} on sucrose content and cane yield. The dry matter production of leaves, sheath stalk, cane height and weight markedly increased up to 70 m^3 ha^{-1} supply of the effluent. Sucrose content in cane juice showed a significant enhancement due to effluent up to 35 m^3 ha^{-1} and reducing sugars showed a linear increase up to 140 m^3 ha^{-1} supply. Raw tannery effluent reduced N, P and K uptake by finger millet crop but the diluted effluent increased the uptake (Kumaravelu *et al.* 2000).

2.1.1.6 Other effluents

Jensen (1981b) found that irrigation with potato factory effluent increased yields of barely, rye, oats, rape, potatoes, beet and grass by 13.4, 14.3, 28.9, 8.1, 4.4, 8.9 and 53.1 hay kg ha^{-1}, respectively compared to irrigating with normal water and application of P and K fertilizer. A field study conducted by King (1982) showed that grass yields with untreated and treated industrial waste water was equal to or greater than yields with control. Recovery of nitrogen applied through waste water ranged from 20 to 30 %.

Ajmal and Khan (1984a) reported that germination of pea and wheat seeds were 80 % and 90 %, respectively when raw undiluted brewery effluent was used for irrigation. The germination's were 100 % in both the crops with 50% and 25 % brewery effluents. The growth of the plants was maximum in soil irrigated with 50 % effluent.

Smith and Hayden (1984) reported the nitrogen from potato processing waste water to produce a maximum corn yield with about 200 kg N ha^{-1} annually. Kansal and Singh (1983) observed that the plants (maize, berseen, cauliflower, spinach) collected from municipal waste water irrigated soils had considerably higher contents of Fe, Mn, Zn, Cu, Pb and Cd than those from tube well irrigated soils.

Khatri and Jamajum (1988) based on field trials conducted on a clay loam soil observed that sewage water irrigation increased the total dry matter yield of sweet corn. The Ni, Cd, and Pb content in leaves and seeds were unaffected by irrigation with treated waste water, whereas the content of N and K increased The P content tended to get reduced marginally.

Marecos *et al.* (1989) observed higher yield of sorghum crop with sewage water than plots irrigated with potable water and given commercial fertilizers, suggesting that the nitrogen content of waste water can replace the commercial fertilizers. No significant crop composition changes were noticed.

Tripathi *et al.* (1988) observed maximum tuber yields with treated sewage effluent irrigation (28 t ha^{-1}) followed by raw sewage (22 t ha^{-1}) and tube well irrigation (16 t ha^{-1}). Very low concentrations of heavy metals (below permissible limits) were observed in tubers from the raw sewage irrigations treatments.

Stahl and Williams (1986) reported that oil shale process waste water was toxic and lethal to blue bunch wheat grass, whereas, in a pot culture study Stehlik (1987) observed that undiluted yeast factory waste water had little or no inhibitory effect on *sinapsis alba* germination. The dry matter and fresh yields increased up to 50 times diluted waste water irrigation. Plant Ca, Mg and P content reduced and Na content increased by the mixed waste water application.

Singh *et al.* (1991) studied the effect of refinery effluent on yield and heavy metal contents of berseem grown on a salt affected soil. The results indicated that the dry matter yield of berseem decreased significantly with increasing number of irrigation with refinery effluent water. The concentration of Fe, Mn, Zn, Cu, Pb, Cd, Ni and Cr in plant tissues increased significantly with increasing number of irrigation.

Traka *et al.* (1998) studied the effects of treated effluent from a waste water plant or a nutrient solution on the production of green house tomatoes, in combination with two substrates [perlite and a 1:1 mixture of perlite and zeolite] in Thessaloniki, Greece. Fertigation with treated waste water, without supplying additional nutrients improved fruit quality (% of soluble solids) but increased the incidence of blossom-end rot. The pH of the fruit juice and fruit firmness, were not affected. The number of marketable fruits decreased by 18 %, their total weight decreased by 34 % and mean fruit weight decreased by 13 % in comparison with fertigation with the nutrient solution. Reduction in fruit yield and increases in physiological disorder caused by unbalanced nutrition could be corrected by adjusting the concentration of nutrients in waste water effluent.

Gladis *et al.* (1999) to study the effect of waste water irrigation and graded levels of N and P fertilization on hydrogen cyanide (HCN) and nitrate content of fodder sorghum Var. Co-27. The HCN and NO_3 contents were high in waste water irrigated fodder and the highest value was registered with cattle shed wash. Application of N increased and that of P decreased these toxic components in fodder. As crop advanced, a decrease in HCN and NO_3 contents was observed. The trends suggested that a delayed harvest of the fodder would extremely prove safe.

Influence of treated sewage and tube well water irrigation with different fertilizer levels on rice was studied by Tiwari *et al.* (1996). With eight treatments combination involving four levels of fertilizer (0, 25 %, 50 % and 100 % RDF) and two levels of water i.e. tube well water and treated sewage water. They found that 50 % of fertilizer for production of rice could be saved when rice crop was irrigated with treated sewage water.

Ranwa (1999) recommended that treated waste water when used in low concentration with canal and tube well water may have a good effect in crop growth and yield. The direct use of waste water in high concentration should be avoided for its reuse in agriculture.

2.1.2 Cumulative effect of effluents

2.1.2.1 Sewage effluent

Narwal *et al.* (1991) conducted a green house study to investigate the effect of nickel enriched sewage water on the accumulation of nickel and other heavy metals in corn. They found that corn yield varied depending upon the level of Ni and nature of soil. Lower levels of applied Ni showed beneficial effect on corn yield. Whereas, at higher levels there was sharp reduction in yield. The maximum reduction in yield occurred at 200 ppm Ni. Application of sewage water for eight years to soil did not result in accumulation of Ni, Zn, Fe, Mn and Cu in the plant tissues. Nickle showed a synergistic effect on the uptake of Mn and Fe, but the levels of these metals were within the concentration range considered to be normal for plant growth.

Cambell *et al.* (1983) studied to assess the long-term effects of applying municipal waste water on agricultural land under semi-arid condition of alfalfa, sweet corn and wheat crops. Plants grown on effluent irrigated sites had greater growth rates, dry weights and yields than did plants grown on irrigated control sites. Chemical analysis for metals in plant parts showed that Na was higher in plants growing on the waste water site, whereas Cu, Fe and Zn were much higher in plants harvested on control sites.

Jayaraman (1988) studied the effect of different nitrogen levels on forage yield of bajra hybrid under sewage irrigation. Irrigation with sewage effluent gave higher yields in the 2nd year than in the 1st year. Datta *et al.* (2000) studied the effect of long-term application of sewage effluents on fodder crops. They indicated enhance K removal as a result of higher dry matter production. They also observed that concentration of metals in all crops were below the generalized critical level of phytotoxicity except Fe. Plant analysis revealed that metal toxicity has still not inflicted these soils inspite of these having been irrigated with sewage effluents for more than three decades. Among the different crops (Citrus, chillies, brinjal, hybrid brinjal, carrot, bottle guard radish and rose), citrus and rose was poor accumulators of metals and could be grown on metal polluted soils and growing of the vegetables on such soils could be avoided.

2.1.2.2 Industrial effluent

Day *et al.* (1976) indicated that, cotton, sorghum and barley grown in rotations and irrigated with standard sludge treated waste water containing 24 mg N, 8 mg P and 10 mg K L^{-1} or given N P K fertilizer and irrigated with well water produced comparable yields.

Yoshika (1981) conducted a field trial for ten years irrigating different crops with waste from a potato starch factory and found that application of 20 L

m^{-2} resulted in excessive vegetative growth in maize and wheat. He also concluded that the quality of effluent water to be used for irrigation should be based on the optimum quantity of K requirement of the crop and N and P should be applied as fertilizer.

Field trials on agricultural crops were conducted during 1986-87 at Rastriya Chemicals and Fertilizer Ltd. Thal (Maharastra) by using urea factory effluent of 50 to 600 ppm N concentrations as irrigation and nitrogen sources Nitrogen added through effluent during the crops season ranged between 22.8 and 1583.1 kg ha^{-1}. Effluent irrigation and fertilizer increased the forage and grain yields of maize. Grain yield of maize was recorded 3.83 t ha^{-1} when irrigated with effluent of 600 ppm N concentration with basal dose of P_2O_5 and K_2O @ 30 : 30 and 60 : 60 kg ha^{-1} generated maximum grain yield of 6.0 and 4.10 t ha^{-1} during 1986 and 1987, respectively. The performance of groundnut and jute crop under effluent irrigation at higher input rates of phosphorus fertilization showed that percent increment in yield of groundnut pod and jute grain over conventional recommended practices and maximum percent increment was noticed to be 49.8 and 80.4, respectively (Bahirat *et al.,* 1989).

In a lysimeter study Totawat (1991) observed that zinc smelter effluent did not alter the yields of *kharif* and *rabi* maize, urid, gram and wheat crops. The diluted smelters' effluent when used for irrigation increased the content of zinc in seed and stover of *rabi* crops, but did not have any effect on combination of *kharif* crops.

Pathak *et al.* (1998) carried out a field experiment to study the feasibility of distillery effluent for irrigation. During *rabi* and *kharif* seasons of 1993-94, wheat and rice were grown in sequence on the farm of Oath sugar mills, Sitapur (U.P.). They found that application of distillery effluent increased the biomass yield of wheat and rice. Similarly, Achari *et al.* (1999) studied the effect of paper mill effluent on the yield of rice and reported that effluent irrigation did not affect the grain and straw yield of rice in both the seasons.

2.2 Effect of effluent water on soil changes

Use of effluent as irrigation water has been reported to affect the soil markedly. It has been reported that effluent water reduces the soil pH (Intraweck *et al.*, 1982), affects the microbial population (Emmiamath and Rangaswami, 1971), retards the nitrification process (Pang *et al.*, 1975), increases ground water pollution (Smith, 1976) results in accumulation of salt (Subbiah and Ramula, 1979) and increases losses of N through leaching, volatilization and denitrification (Smith, 1976), but if used in a proper way, it may not create any problem and many times it has been reported to improve the soil productivity (Adarkatti and Rao, 1980 and Anon., 1989).

2.2.1 Direct effect of effluent on soil changes

2.2.1.1 Distillery effluent

Singh (1961) used neutralized spent wash and observed marginal decrease in soil pH. The values regarding total nitrogen, total and available potassium and available phosphate were found higher in treated plots with spent wash than in control. Similarly Yang (1968) applied diluted spent wash (1:3) with chemical fertilizer and studied soil properties after harvest of sugar cane crop. He noticed increase in available K status of the soil.

With a view to study the utility of spent wash (distillery effluent) for its manurial value an experiment under field condition was conducted by Bajpai and Dua (1972) at Rampur Sugar factory farm. Due to addition of 20 times diluted distillery effluents, the pH value were not affected while organic carbon content was decreased and N content was increased. In a small scale field trial Subba Rao (1972) studied accumulation of salts and organic matter in the soil due to application of 10 times diluted anaerobic lagoon treated spent wash as a source of irrigation water. He noticed increasing available K to the extent of about 5000 kg ha^{-1}. The soil pH was increased from 7.5 to 8.0 and EC from 0.1 to 0.4 dSm^{-1}. On the basis of 1 year dates he concluded that addition of distillery effluent had no deleterious effect on soil properties and on the crop yield.

Somawanshi and Yadav (1990) conducted a soil column experiment with spent wash (distillery effluent) on soil chemical properties and composition of leachate at Rahuri. They observed that very dilute spent wash did not add much of the soluble salts to the soil, if sufficient soil solution was drained out. But higher quantity of concentrated spent wash would build-up the salt load particularly of Cl^- and SO^{-4} of Ca, Mg and Na both in the soil and in the underground water.

Zalawadia and Raman (1994) studied the effect of diluted distillery waste water on sorghum crop grown in a clayey Typic Chromustert and indicated that, after the crop harvest, the electrolyte conductivity, organic carbon, available N, P and K in soil were higher with the use of effluent water than the normal water at the same level of fertilizer application. Similarly Devarajan and Oblisami (1995) observed that soil pH, salinity, N, P, K, Ca and Mg content were increased with the distillery effluent irrigation as compared to normal irrigation water.

2.2.1.2 Industrial effluent

A field study was conducted by King (1982) to determine whether untreated industrial waste water can be applied to soil without adversely affecting crop growth and soil properties or posing ground water pollution hazard. The result indicated that waste water irrigation increased the concentration of P, K, and Ca in soil and increased soil pH (7.4 to 7.8), sodium accumulated in sub soil to an exchangeable Na percentage of 10.

Ajmal and Khan (1984a) observed that the application of brewery effluent to the soil increased the contents of available nutrients in the soil. The content of available potassium, organic matter, ammonical nitrogen and phosphorus increased while the pH decreased, with increasing concentration of the effluent. The $CaCO_3$ content of the soil decreased when irrigated with 100 % or 75 % effluent, while it increased with 50 % to 25 % effluents. The surface soil had higher values of N, P, K and organic matter than the sub-surface soil. They (1984b) further studied the effect of vegetable ghee factory effluent in four different concentration (25 %, 50 %, 75 % and 100 %) on certain physico-chemical properties of fertile soil. The effluent at all dilutions raised the concentrations of water soluble salts, $CaCO_3$, NH_4-N, potassium, phosphorus and organic matter of the soil. The greatest changes were, however, caused by the undiluted effluent.

In the soil irrigated with dairy processing effluent, there was increase in the pH, organic carbon, $CaCO_3$, water-soluble salts, cation exchange capacity, nitrogen and phosphorus (Ajmal *et al.,*1984). Addition of oil shale process water in the soil, increased concentration of Ca, Mg, Na, NO_3 and NH_4 nitrogen and electrical conductivity of the soil (Stahl and Williams, 1986). Rasiah *et al.* (1990) reported that the oil refinery effluent reduced the water retention in soil by approximately 10 % but increased the saturated hydraulic conductivity by about 50 %.

Sivaswami (1990) studied the effect of tannery effluents and tannins on microbial population and nutrient states of the soil. In taniliquor treated soil, Azotobacter population increased whereas, bacterial and fungal population decreased. Except nitrogen copper and iron all other elements contents increased. In 1991, he subsequently reported that the taniliquor treatment slightly reduced the pH and available N of the soil, whereas, tanin amendment increased N, P and K content in soil. But depleted copper and iron in soil and improved manganese status and increased slightly Zn status of soil.

A pot experiment was carried out by Singh *et al.* (1991) to study the effect of refinery effluent on the yield and heavy metal content of berseem grown on a salt affected soil. The results indicated that DTPA extractable Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn contents in the soil increased significantly with increasing number of refinery effluent irrigations. Totawat (1991) found that the use of of diluted zinc smelter's effluent for irrigation resulted in several hundred-fold increase in DTPA extractable Zn in the surface layer of soil. A marked build-up of the available metallic cations especially Fe, Zn and Cu occurred at a depth of 60 cm in soil. The accumulation was more in fine textured soil than in soil with low clay content.

Malti *et al.* (1998) carried out a field experiment at Agricultural College Research Institute, Killikulam (T.N) to study the influence of the paper factory effluent on soil available micronutrients and yield of rice. They reported that diluted effluent irrigation (1:1) increased the available N, K status whereas, P status in soil decreased.

A pot experiment with maize was set up to evaluate agricultural usefulness of a by product containing ammonium sulphate and ammonium nitrate obtained during simultaneous desulphurization and denitrogenization of power station flue gases as a fertilizer by Niedzwiecki *et al.* (2000). They observed similar effects on the contents of total N, available K, P and Mg, total major elements (K, P, Mg, Ca, Na) and trace elements (Co, Cd, Ni, Pb, Cu, Fe) in the soil except that the by product ammonium sulphate decreased the soil reaction.

The tannery effluent irrigation increased bulk density, pH, Electrical conductivity and organic carbon of soil in pot culture condition after harvest of finger millet crop (Kumaravelu *et al.*, 2000).

2.2.2 Cumulative effect of effluents on soil changes

2.2.2.1 Distillery effluent

Escolar (1966) reported that the application of four acre inch of distillery slops and black strap molasses had a favourable effect on soil aggregates stabilization in the clay soil. Soil hydraulic conductivity values tended to increase. The relatively high content of water stable aggregates in the soil at the time of removal of fourth crop indicated resistance to decomposition of the organic cementing or binding agent present in the slops and molasses.

A preliminary laboratory experiment was undertaken by Jadhav (1973) to study the influence of anaerobically treated spent wash used as irrigation on some physical and chemical properties of non-calcareous medium black soil. He reported that, due to periodical addition, the soil pH increased slowly, whereas, EC, water-soluble cations and anions, sodium adsorption ratio and potassium adsorption ratio increased rapidly There was beneficial effect of periodical spent wash addition on available N, P and K contents of the soil. Pathak *et al.* (1998) studied the feasibility of distillery effluent for irrigation in sandy loam soil on wheat and rice grown in sequence at Sitapur (U.P.) Application of effluent increased the EC in the post harvest soil after wheat crop. However, the EC of the soil after rice crop decreased. There was not significant change in soil pH due to application of effluent after wheat and rice crop. An increase in organic carbon content as well as K status was observed with effluent application.

2.2.2.2 Industrial effluent

Kannan and Oblisami (1990) reported that the irrigation of sugarcane crops with combined pulp and papermill effluent increased soil pH, organic carbon, N, P, and K. Over a period of 15 years, effluent application increased exchangeable Na by 4.5 fold compared with control soil (Well water irrigation). Similarly the soluble salt, organic carbon and available K content in sandy loam soils of Coimbatore was observed due to prolonged use of a paper mill effluent by Palaniswami and Ramulu (1994).

Bansal *et al.* (1992) while working at Punjab Agricultural University, Ludhiana on accumulation and bio-availability of Zn, Cu, Mn and Fe in soils polluted with industrial waster water (IWW) found that soils irrigated with IWW had lower pH but higher organic carbon as compared to those, which received tube well water (TW) as a source of irrigation. DTPA extractable Zn, Cu, Mn and Fe largely accumulated in the upper 15 cm depth and the extent of their accumulation depended on the period of use of IWW. In the 0-5 cm soil layer the respective value of DTPA available Zn Cu, Mn and Fe were 0.9, 1.6, 5.2 and 28.5 mg kg^{-1} soil where tube well water was used for irrigation and the use of IWW for five consecutive years increased these values by 52, 16, 4 and 3 times, respectively. The bioavailability of these elements to wheat depended not only on their content in soils but also on the levels of interacting metal ions.

Achari *et al.* (1999) studied the effect of effluent of the paper mills. Soils irrigated with papermill effluent revealed higher pH and EC. Effluent irrigation in general increased the available N and K and decreased available P. DTPA extractable Fe, Mn, Zn and Cu were also increased due to effluent irrigation. Malti *et al.* (2000) at Cheramahadevi (T.N.) observed that soils irrigated with paper mill waste water increased the pH and EC in both the seasons of rice crop. Gypsum was better in lowering pH than rice husk ash, whereas, for EC the rice husk ash was proved better. DTPA extractable Zn, Cu, Fe and Mn largely accumulated in the upper 15 cm soil depth and the extent of accumulation was increased with increased time of application.

2.2.2.3 Sewage Water

Kuhad *et al.* (1989) studied the mobility and accumulation of heavy metals in agricultural soils receiving sewage water irrigation enriched with heavy metal industry effluents. The soil was highly contaminated with Cd, Pb, Ni, Zn, Cu and Fe due to long term use of raw sewage waters for irrigating crops. Maximum accumulation of heavy metals was observed in the surface horizon. Khatri and Jamajum (1988) reported that waste water usage increased soil EC and organic matter content of surface soil compared with normal water. Further, the waste water irrigation greatly increased extractable soil P and K. The trace nutrients were slightly increased and heavy metals were not affected.

In a loamy sand soil where liquid sewage sludge of Cairo city was used as source of irrigation Abdou and Nennah (1980) reported that with the use of liquid sewage sludge year after year, the total and soluble forms of micronutrients (Fe, Mn and Zn) increased in the soil. Subsequently Nennah *et al.* (1982) found that use of sewage effluent increased soluble boron and heavy metals (Pb, Cd, Cu, Cr and Co) in soils of Cairo.

Long term sewage irrigation increased soil organic matter content and improved the physical-chemical and hydrological properties of the soil (Bocko, 1980). The influence of territory treated domestic effluent on 14 soil biochemical properties was studied in a Monterey pine (*Pinus radiates*) forest on volcanic soil. The soils were irrigated with either effluent or water with two ordinary rates (49 and 75 mm wk^{-1}) surface soils (0-5 cm) were collected from the effluent irrigated and adjacent non-irrigated control sites annually for 3 yrs and for 2 yrs from the water irrigated sites. Effluent irrigation significantly increased pH, invertase activity, denitrification, mineralizable N and extractable nitrate. These increases were not observed in the water irrigated soil, suggesting that changes resulted from effluent chemistry rather than additional water loading. Phosphate activity decreased with both water and effluent irrigation. No changes were observed in a total N, total K, basal respiration, microbial biomass, sulfatase activity or extractable ammonium in the effluent and water irrigated soils. Both rates of effluent application had the same effect on soil properties indicating that the threshold rate, which changed soil properties was 49 mm of effluent per week (Schipper *et al.*,1996).

Datta *et al.* (2000) compared the soil properties between sewage effluent irrigated soil and tube well water irrigated soil at IARI, New Delhi. In sewage effluent irrigated soil variation ranging from 7.1 to 8.4 in pH and 3.5 to 7.7 g kg^{-1} in organic carbon. The corresponding value of pH and organic carbon in tube well water irrigated soils were 7.3 to 8.4 and 3.7 to 5.8. Accumulation of available P occurred in sewage effluent irrigated soil, such an increase was 180 % on the contrary decrease to the extent of 20% was in available K. DTPA extractable Zn, Cu, Fe, Mn, Ni and Pb content were increased by 127, 200, 22, 247, 100 and 29 % due to long term use of sewage effluents over adjacent soils irrigated through tube well water. The DTPA extractable Cd and Co were below the limits of analytical detection.

2.3 Effect of solid waste on crop growth, nutrient accumulation and quality

2.3.1 Direct effect

2.3.1.1 Industrial solid waste

Sawarkar and Dikshit (1990) conducted a green house experiment with maize and soybean in Kharif 1987-88 on a soil (chromustert). Oxalic acid manufacturing waste material was applied @ 0, 10, 20 and 30 t ha^{-1} in both the experiments. They found that dry matter yield of maize and soybean increased with increasing levels of waste material. This increase was about 70 % with highest level of waste material (30 t ha^{-1}) over control because of waste material contained 16 % sulphur. They also noted the increase in uptake of sulphur, phosphorus, potassium, calcium and magnesium with increasing levels of waste material.

Kumar and Mishra (1991) studied two types of pressmud cake (sulphitation and carbonation) on the growth of rice. They revealed that application of either type of pressmud cake was beneficial for rice, but the application of pressmud cake was most beneficial up to 10 t ha^{-1}, beyond which the response decreased. Further more, total N, P and K uptake by rice plants increased with increasing dose of pressmud cake up to 10 t ha^{-1} but above this dose, a marked decrease occurred. The material obtained by sulphitation process appeared to be better than the one obtained by carbonation process.

Patel and Singh (1991) studied the effect of application of gypsum (25 and 50 % of the gypsum requirement), pressmud and pyrites (@ 25, 50 and 75 % of gypsum requirement) on yield of rice under percolated and unpercolated condition on silly loan (sodic) soil. They showed that different levels of amendment significantly increased yield of rice and wheat. The highest yield of rice was recorded with pressmud followed by gypsum and pyrites. Pyrites was found to be as effectives as one third of gypsum when applied on total sulphur content basis.

Three years field experiment was carried out by Kapur and Kanwar (1993) at Jalandhar on a normal sandy loam soil (Typic Ustochrept) involving treatments of 10 and 20 Mg ha^{-1} each of sulphitation filter cake (SFC), carbonation filter cake (CFC) and farm yard manure (FYM) alongwith a control. SFC showed better effects in increasing root sugar yield of sugarbeet than FYM. The application of 10 and 20 Mg ha^{-1} of SFC increased the root yield by 21.9 and 48.3 % in comparison to 15.9 and 31.4 % under FYM. The increase in sugar yield was 22.6 and 45.4 per cent in SFC compared to 17 and 35.4 % in FYM. The total uptake of N and P by the sugarbeet crop was also highest in SFC and lowest in CFC treated plots. K uptake, however, was highest in FYM and lowest in SFC treatments.

Sarkunan *et al.* (1993) studied effect of ferrochrome slag on the yield and nutrient content of rice on acid soil (Ultisol), The slag was applied @ equivalent to 0, 0.25, 0.50, 1.00 and 1.50 times the lime requirement (L.R). They found that application of slag did not cause any adverse effect on rice plants, but increased grain straw yields up to 0.5 L.R. levels of its' addition. At higher levels, the yield, however, decreased. The P content in both grain and straw increased up to 0.5 L.R. levels of slag addition and decreased thereafter. The slag addition however, significantly decreased K, Fe and Mn content in both straw and grain and Cu and Zn in straw while Ca content showed an increase.

Abubacker and Rao (1993) carried out a pot culture study maintaining 10, 20 and 30 % concentration of press mud cake along with control on rice crop. They indicated that Sheath length was maximum in 20 % concentration of pressmud cake, root and leaf length was maximum in 30 % concentration of press mud. The fresh and dry weights were also maximum in 30 % treatment.

The moisture content was maximum in 20 % treatment of pressmud cake whereas, biosynthesis of some enzyme was more in the plants treated with 10 % pressmud cake.

Pressmud application was found as the best for paddy nursery in South Gujarat condition. Application @ 20 t ha^{-1} reduced the nitrogen and phosphorus requirement through fertilizers by 50 %, though with full dose there was additional effect (Anon., 1994).

Green house and laboratory experiments were carried out with Vertic Ustochrept by Patil and Shinde (1995) to study the effect of spent wash, spent slurry and pressmud composts on maize. Air dried 8 kg soil was placed in earthen pot after mixing it with 1.5 per cent spent wash and spent slurry composts, FYM, pressmud and lagoon-dried spent wash solids (SWSL) and spent wash liquid (SWL). Spent wash / spent slurry (2:1, 3:1, 4:1, 5:1 and 6:1) were composted in laboratory with pressmud. The 200, 75 and 150 ppm N, P, K respectively were applied. They found that application of FYM and spent slurry (3:1) composted increased maize plant height over control. While remaining treatment were at par with control. FYM, spent slurry 3:1 and 5:1 compost and spent wash 6:1 compost resulted in significantly higher dry matter of maize than control. While, SWL showed a decrease. The FYM proved better than all other sources except spent-slurry (3:1) and (5:1) and spent wash (6:1) composts. The SWL treatment showed significant decrease in plant Zn uptake than control. The uptake of Cu also decreased for this treatment compared with FYM, PM, SWSL and higher ratio composts.

In a field experiment Trivedi *et al.* (1995) showed increasing efficiency of fertilizer phosphorus through addition of organic amendment in groundnut in Jalalpur series of Navsari Ustochrept great group. They also indicated that phosphatic fertilizer applied in conjunction with FYM and pressmud increased pod and haulm yield of groundnut, total P uptake combined application of P and organic amendments showed higher beneficial effects. Application of pressmud @ 5 t ha^{-1} + P @ 22 kg ha^{-1} proved superior for all parameters.

In a laboratory condition sterilized oxalic acid (a problematic waste of oxalic acid industries of M.P.) as a carrier for Rhizobium inoculants and its' effects on soybean were studied by Kaushal *et al.* (1996). They allowed Rhizobium to multiply at both the temperature (ambient i.e. ranging from 7.5 to 30 C° and 40 C°) up to 90 days as compared with lignite. Nodular mass, grain yield and nitrogen contents of shoots of soybean were substantially increased by the bionoculant development from sterilized oxalic acid industrial waste.

Raman *et al.* (1996) carried out a three years field experiment to know the feasibility of some industrial wastes for soil improvement and crop production. The treatment consisted of three industrial by product/waste viz., gypsum, flyash and pressmud and each was applied @ 6 t ha^{-1} in absence and presence of rice straw @ 5 t ha^{-1}, with one absolute control. Application of all these materials resulted in significantly higher grain and straw yield of sorghum crop. The cost benefit ratio analysis indicated that pressmud was slightly better than flyash, though, all the three when applied alone were superior to control.

Dang and Verma (1996) carried out a green house experiment to study the sulphitation pressmud cake (SPMC) and Carbonation pressmud cake (CPMC) to determine the fertilizer equivalence of pressmud cake for rice and the residual effect on succeeding wheat crop. Application of either type of cake was beneficial for rice crops. The SMPC was better than CPMC. The fertilizer equivalence of 10 t ha^{-1} of SPMC was 50 per cent while that of CPMC was 28 per cent of fertilizer recommendation for rice.

Tiwari *et al.* (1998) studied long term effect of press mud and nitrogenous fertilizer on sugarcane and sugar yield at Sehore (M.P.) They found that continuous application of pressmud and nitrogenous fertilizer significantly increased sugarcane crop and sugar yield and also increased available soil nitrogen.

A field study was conducted for four seasons from 1997-1998 at Tamil Nadu Agricultural University Farm, Coimbatore on Alfisol by Selvakumari *et al.* (2000). The results of the pooled mean analysis indicated that the treatments, which received flyash @ 20 and 40 t ha^{-1}, recorded a rice yield increase of 10.3 and 16.6 per cent, respectively over no flyash addition. The highest yield was recorded when flyash applied was @ 40 t ha^{-1} in combination with fertilizer, compost and Azospirillum. The significant increase in the uptake indicated that fly ash could serve as a source of plant nutrients.

2.3.1.2 Sewage Sludge

Sludges of controlled metal addition were used in pot trial by Sanders *et al.* (1987) to assess effect of sludge borne, Zn, Cu and Ni on the growth of clover, barley and red beet in sandy loam soil (pH 6.5). No phytotoxic effects of Cu and Ni on crop yields were measured at the maximum soil concentration used of 95 mg Cu kg^{-1} and 77 mg Ni kg^{-1}. The total concentration of Zn in the same sensitive soil likely to give rise to critical tissue concentration was estimated as 250 ppm. Similarly Mark (1980) also reported that sludges contained more less normal amount of Zn, Cu and Ni were applied at approximately 20, 40, 70 and 150 t ha^{-1} (dry solids). No phytotoxic effect on crop yield were measured even though soil metal content was raised to 79 mg Ni kg^{-1}, 237 mg Cu kg^{-1} and 474 mg Zn kg^{-1}.

Carlton Smith and Stark (1987) showed that very little Pb was taken up by ryegrass and concentration in plant tissue were independent of the levels in soils, which increased to a maximum value of 25000 mg Pb kg^{-1} in the sludge treated soil examined. Vigerust and Selmer Olsen (1986) similarly confirmed that there was no crop uptake of Pb from sludge treated soils. Koeppe (1981) concluded that Pb had no toxic effects on plants due to low bioavailability and because any absorbed Pb is immobilized in the roots. Pollard (1991) also reported the same confirmation. He noted the concentration of Pb in ryegrass grown on a sludge treated soil in the field was typically about 8 mg kg^{-1} for a soil containing approximately 1760 mg Pb kg^{-1}

Carlton Smith (1987) assessed dietary intake of Cd arising from the utilization of sludge in agriculture. The field experiment was conducted at three sites on soil and the trial was conducted over five growing seasons. The six crops grown were selected to include major constitute of the human diet (wheat, potatoes and cabbage) sensitive indicator crops (red beet and lettluce) and rye grass was also included. The concentration of Cd in crop tissues approximated to a simple linear function of the total concentration of Cd in soil and amounts in the crops grown decreased in the order lettluce > redbeet > wheat > rye grass > potatoes > cabbage.

Ramchandran and D'Souza (1999) conducted green house experiment to evaluate the uptake of Cd, Zn and Mn by two successive maize (*Zea mays* L.) crops from increasing levels of Cd enriched sewage sludge and city composts, amended Ultisol, Alfisol, Entisol and Vertisol. A significant yield reduction of maize shoots of both first and second crops was obtained only in Ultisol and Alfisol amended with higher rates of Cd-enriched sewage sludge / city compost. Amending the four soils with Cd-enriched sewage sludge / city compost resulted in significantly higher accumulation of Cd and Zn in the successive maize crops. The plant tissue concentration of Mn was significantly reduced in Ultisol, whereas, an enhancement was noticed in Alfisol and Entisol and no significant differences were obtained in Vertisol.

A pot experiment was conducted by Singh and Pandeya (2000) to study the influence of application of organically complexed Cd on rajmash (*phaseolus vulgaris* L.) on ten sewage sludge treated old alluvium, non calcareous and non saline soils of Patna wherein a ' rajmash" crop was grown after treatment with 0 and 5 mg kg^{-1} isotopically tagged and organically complexed Cd. The results indicated that the application of Cd through cadmium-fulvic acid complex in soil did not influence the dry matter yield of the crop, though it significantly increased the concentration of Cd in the plants and it's uptake by the crop.

Ortiz Hermandez *et al.* (1999) found no toxicity or undesirable high levels of heavy metals in maize crop due to application of sewage sludge for two years in Vertisol soils.

2.3.2 Residual effect

Kumar and Mishra (1991) carried out a green house experiment to study the effect of two types of pressmud cake (sulphitation and carbonation) on growth or rice-maize. They observed that both types of pressmud cake were found beneficial for residual maize crop up to 10 t ha^{-1}, beyond which the response decrease. Total N, P and K uptake by maize plants increased with increasing dose of pressmud cake up to 10 t ha^{-1} but above this dose a marked decrease occurred. The material obtained by sulphiatation process appeared to be better than the one obtained by carbonation.

Dang and Verma (1996) conducted a green house experiment to study the sulphitation pressmud cake (SPMC) and carbonation pressmud cake (CPMC) to determine the fertilizer equivalence of pressmud cakes for rice and residual effect on succeeding wheat crop. Application of both type of cake was found beneficial for wheat crop. The residual effect of CPMC on wheat showed improvement in its' efficiency but was lower than the SPMC.

The residual crop yield was significantly increased over N P K treated control by conjunctive use of basic slag with green leaf manure at higher level was observed by Mohandas and Appavu (2000) at Madurai in sandy clay loam soil.

2.4 Effect of solid waste on soil changes

2.4.1 Direct effect

2.4.1.1 Industrial waste

Sweden and Atkinson (1951) studied the effect of waste sulphite liquer solids (WSLS) on changes of light and heavy soils. They found that WSLS greatly increased the percentage of larger water stable aggregates and decreased the pH of both the soils. The WSLS also increased the organic matter content and moisture equivalent particularly in loamy sand soil.

In the soils of Madurai (T.N.) Mayalagu (1983) observed that both coir waste and pressmud reduced the bulk density from 1.54 to 1.13 g cm^{-3} with tremendous increase in the infiltration rate. While evaluating the effect of coir pith in the medium black soils of Tamil Nadu, Nagarajan *et al.* (1986) observed that coir pith either alone or with culture on NPK did not affect the soil pH, N and P values, but the K values increased substantially.

Sewaram *et al.* (1992) reported that infiltration rate was increased by about 50 % along with mean weight diameter of aggregates due to pressmud application @ 4 t ha^{-1}, in the clay loam soils of Dehradun. While in black soil at Rahuri, application of pressmud @ 15 t ha^{-1} reduced bulk density slightly with a small increase in the water stable aggregate values and hydraulic conductivity value two fold (Shinde *et al.* 1995).

A three years field trial on Vertic Ustochrept showed that application of gypsum reduced soil pH and increased the electrolyte conductivity. Fly ash and pressmud did not have any effect on soil pH and EC, but organic carbon content significantly increased due to pressmud application. Application of all the three materials enhanced the infiltration rate. The water stable aggregates were also significantly higher in the amended soils and pressmud was found to be the best (Raman *et al.,* 1996).

Dang and Verma (1996) observed increase in organic carbon, available P, K, and Zn in soil from the use of sulphitation pressmud cake than from the carbonation pressmud cake. However, the use of carbonation pressmud cake showed slight increasing trend in pH and $CaCO_3$ contents.

Chithra *et al.* (1998) studied the impact of organic waste on the nitrogen availability in rice soils of Thambirabarani river tract. Application of organic wastes irrespective of the source recorded increased available N status of soil over no organic in both the seasons. Green leaf manure treated plots recorded the highest values at all stages followed by the treatments in order of composted coir-pith > pressmud > FYM > composted sugar cane trash > raw coir-pith >raw sugarcane trash.

The influence of sludge addition (0.5, 1.0 and 2 % of soil sample) on the physical and chemical properties of the soil was studied in pot experiments by Mohamed and Awad (1998). Bulk density in sandy soil decreased with addition of sludge (from 1.72 to 1.65, 1.55 and 1.55 g cm^{-3} with 0.5, 1.0 and 2 % application rate, respectively). Loam soil followed a similar trend with decrease from 1.58 to 1.50, 1.41 and 1.3 g cm^{-3}, respectively. Hydraulic conductivity decreased in sandy soil from 14.58 to 9.32 cm hr^{-1} but increased in loam soil from 5.92 to 6.94 cm hr^{-1}. The organic matter, total nitrogen, CEC, total porosity, EC, WHC, FC, WC and available water were increased in sandy and loam soil following the addition of sludge.

Fierro *et al.* (1999) carried out an experiment at Quebels, Canada to study the application of papermill sludge along with N and P fertilizer on soil physical properties. The sludge was incorporated at 0 and 105 t ha^{-1} before seeding tall wheat grass. Nitrogen at (315, 630 and 945 kg N ha^{-1}) and P at (52.5 and 105 kg P ha^{-1}) were also applied to all plots. After 823 days C concentration were 43 and 69 % of that day 5, for the low and high N rates, respectively. With time the proportion of C in the heavy (> 1.8 g cm^{-3}) fraction increased from 20 to 55 % but remained near 20 % in the fine (< 53 g cm^{-3}) fraction.

Selvakumari *et al.* (2000) noted a significant increase in EC, exchangeable Na, available P, K, Ca, Mg, S and Si in the post harvest soil after fourth crop of rice under continuous addition of lignite flyash. The increase in pH was not significant. The results also confirmed that even after continuous addition of flyash for three seasons, there were no hazardous levels of heavy metal content that would affect soil health and crop production.

A field experiment was carried out by Shrikanth *et al.* (2000) to study the direct effect of enriched composts on soil properties (Alfisol) in comparison with FYM, vermicompost and inorganic fertilizers. They found that pH and EC were slightly decreased in enriched composts treatments. There was significant increased in organic carbon, available N, P and K and exchangeable Ca and Mg in enriched compost of industrial waste treated soil in comparison to other treatment.

2.4.1.2 Sewage Sludge

The long term use of sewage sludge resulted into progressive increase in soil pH, organic matter and P in sandy loam soil (Hani *et al.,* 1996). Whereas, due to oxidization of fifty percent applied organic matter through liquid digested sludge, lowering the soil pH in fine sandy loam soil was observed by Robertson *et al.* (1982).

An experiment was carried out with direct application of sewage sludge on Vertisol soil in mexico by Ortiz Hermandez *et al.* (1999). The soil was used to grow maize annually for two years, using rates from 1 to 5 t ha^{-1}. The composition of sewage sludge having organic matter 50 %, total N 4.93 % phosphorus 1.28 % and different concentration of macro and heavy metals. They found that sludges application was beneficial in providing additional nutrients and organic matter. The pH value was lower at the end of the experiment. Soil nutrients were at normal levels.

Field experiments were conducted on sandy clay loam soils at central farm of Agril. College and Research Institute Madurai to study the effect of added levels of basic slag with green leaf manure on rice. Addition of graded levels of basic slag viz., 500, 750, 1000 kg ha^{-1} significantly increased the soils available P, Ca, Mg, Fe and Si. Application of 1000 kg of basic slag with 12.5 or 18.25 t ha^{-1} of green leaf manure recorded the highest soil available nutrients (Mohandas and Appavu, 2000). Mc Grath and Cegarra (1992) reported the poor movement of Pb through the soil plant pathway was reflected in the very low concentration of Pb present in the soluble and exchangeable fraction of both the sludge amended soil and control soil (which had received only mineral fertilizer) at Woburn. Further more, there was no change in the proportion of soluble and extractable Pb in sludge amended soil with time even though 20 years had elapsed since the last application of sludge to the field. However, Aldridge and Alloway (1993) warned against possible complacency about Pb in sludge amended soil after reviewing more than 400 references on Pb in soils and food crops. They emphasized that soils are dynamic systems responding to changes in environmental factors and that it may be in appropriate to assume that the current environmental and soil chemical condition will persist indefinitely.

2.4.2 Residual effect

Webber (1978) conducted field experiment at Guelph to determine effect of applying up to 376 metric t ha^{-1} of raw, non-segregated shredded solid waste plus 4.6 cm of an aerobically digested sewage sludge. Four years of study with maize they found that soil carbon and nitrogen and water stable aggregation increased, while bulk density decreased with increments of solid waste added. Soil moisture, expressed volumetrically (cm^3 cm^{-3}) and retained at pressure of 0.04, 0.33 and 15 bars and available water was not significantly affected by waste addition.

Kumar and Mishra (1991) reported that soil pH increased and available P decreased by application of carbonation pressmud, whereas, no change in the pH occurred and available P content increased by addition of the sluphitation pressmud. Both types of pressmud increased the organic carbon and available K content of the soil, but the effect of sulphitation pressmud were more pronounced than the carbonation pressmud in rice maize sequence.

Patel and Singh (1991) carried out a green house experiment at Kanpur on silty loam (sodic) soil to study the effect of gypsum, pressmud and pyrites on leachate composition and soil properties. Rice as taken test crop under percolated and unpercolated condition. The residual effect was studied on wheat crop. They reported that gypsum treatments were more effective in removing leachate, Na^+ and Ca^{++} + Mg^{++} whereas, the cumulative removal of CO_3^{--} + HCO_3^- as higher with pressmud treatments than that of gypsum and pyrites under percolated condition. Gypsum was more effective in reducing the pH, ESP and increasing exchangeable Ca and Mg in the soil than the pressmud and pyrite. Soil properties were improved more under percolation condition than unpercolated condition.

Yaduvanshi and Yadav (1996) conducted field experiment to study the residual effect of pressmud cake with nitrogen in sugarcane ratoon at Indian Institute of Sugarcane Research, Lucknow (U.P.). They observed that an increased addition of sulphitation pressmud to plant had a significant residual effect on the increased availability of N, P and micronutrient in the soils for the succeeding ratoon crop. As a result, the cane yield and the quality of cane juice increased significantly due to the increased residual soil fertility. The fertilizer doses for N, P and micronutrient may be reduced considerably in ratoon when sulphitation pressmud is applied to plant crop.

An investigation to study the residual effect of enriched composts, FYM, vermicompost and fertilizer on properties of an Alfisol was carried out at Gandhi Krishi Vignana Kendra, University of Agriculture Sciences, Banglore during 1996 (Shrikanth *et al.*, 2000). The results showed lower pH and higher organic carbon in enriched compost treatments. The higher available N, P and exchangeable Ca and Mg content were observed in enriched composts of industrial waste treatment as compared to FYM and inorganic fertilizer. There was a slight decrease in bulk density of the soil after the harvest of second crop in soil amended with compost compared to inorganic fertilizer treatments.

MATERIALS AND METHODS

III MATERIALS AND METHODS

Keeping in mind the objectives, the investigation was taken up in three parts as below.

i) Assessment of the quality of effluents waters and solid wastes collected from different locations and their feasibility of usage in agricultural crop production.

ii) Pot culture study to evaluate the feasibility of effluents water use with simultaneous reduction in fertilizer application in crop as well as cumulative effect of effluents water on succeeding crop.

iii) Field study to find out the scope of reduction in quantity of fertilizer use through solid wastes usage and their residual effect on succeeding crop.

3.1 Assessment of the quality of effluents water and solid wastes

3.1.1 Industrial effluents water samples and solid wastes were collected from different industries located at Ankleshwar, Vapi, Chalthan and Atul

3.1.2 Analysis of effluents water and solid wastes

After collection and preparation of effluents water\solid waste samples, the physico-chemical characteristics were determined as per standard procedures (Trivedi and Goel, 1984). The methods employed for analyzing different parameters are given in Table-1, while some of the properties of the diluted effluents water, canal water and solid waste used in present study are given in table 2 and 3.

Table 1. Methods employed for physico-chemical analysis of effluents water / solid wastes

Sr.No.	Characteristics	Method employed
1.	pH	Potentiometry.
2.	EC	Salt bridge.
3.	Carbonate	Volumetric titration
4.	Bicarbonate	Volumetric titration
5.	Chlorides	Volumetric titration
6.	Sulphate	Turbidometry
7.	Calcium	Versenate titration
8.	Magnesium	Versenate titration
9.	Sodium	Flame photometry
10.	Potassium	Flame photometry
11.	Nitrogen	Micro kjeldahl
12.	Phosphorus	Colorimetry
13.	Iron	Atomic absorption spectrophotometry
14.	Manganese	Atomic absorption spectrophotometry
15.	Zinc	Atomic absorption spectrophotometry
16.	Copper	Atomic absorption spectrophotometry
17.	Lead	Atomic absorption spectrophometry
18.	Cadmium	Atomic absorption spectrophotometry
19.	Nickel	Atomic absorption spectrophotometry
20.	Cobalt	Atomic absorption spectrophotometry

Table 2. Chemical analysis of diluted effluents water (200 times diluted)

Sr.No	Characteristics	Rallis India Ltd.	United Phosphorus Ltd.	Canal water
1.	pH	6.25	7.94	7.77
2.	EC (dSm^{-1})	2.65	4.83	0.29
3.	Ca^{+2}+Mg^{+2} (me l^{-1})	8.8	7.6	2.20
4.	K^{+} (me l^{-1})	Traces	0.09	Traces
5.	Na^{+}(me l^{-1})	7.75	8.78	0.75
6.	CO_3^{-2} (me l^{-1})	--	--	--
7.	HCO_3^{-} (me l^{-1})	11.2	5.27	2.00
8.	Cl^{-} (me l^{-1})	3.2	5.70	0.18
9.	SO_4^{-2} (me l^{-1})	1.62	22.70	0.82
10.	Fe (ppm)	0.1033	0.0067	Traces
11.	Mn (ppm)	0.092	0.065	Traces
12.	Zn (ppm)	0.005	0.0034	Traces
13.	Cu (ppm)	0.0034	0.0034	Traces
14.	Cd (ppm)	0.0034	0.0017	--
15.	Co (ppm)	0.0067	0.0080	--
16.	Pb (ppm)	0.009	0.007	--
17.	Ni (ppm)	0.013	0.010	--
18.	SAR	3.69	4.50	0.72
19.	RSC (me l^{-1})	2.4	Negative	Negative
20.	Total Nitrogen(%)	0.042	0.055	Traces
21.	Total Phosphorus (ppm)	6.78	0.01	--

Table 3. Physico-chemical properties of industrial solid wastes used in experiment

Sr.No.	Characteristics	Biological sludge	Pressmud	Biocompost
1.	pH	6.6	6.25	7.10
2.	EC (dSm^{-1})	3.46 (1:2.5)	3.68 (1:10)	4.10 (1:10)
3.	Organic carbon (%)	28.7	24.0	19.5
4.	N (%)	2.65	1.25	1.45
5.	P (%)	1.76	2.10	2.80
6.	K (%)	0.08	0.79	1.45
7.	Ca (%)	2.40	2.32	2.42
8.	Mg (%)	12.70	0.40	0.70
9.	Na (%)	0.48	0.02	0.80
10.	Fe (ppm)	9950	5250	7280
11.	Mn (ppm)	340	260	305
12.	Zn (ppm)	232	40	58
13.	Cu (ppm)	304	84	120
14.	Ni (ppm)	150	50	96
15.	Co (ppm)	66	26	30
16.	Cd (ppm)	2	2	4
17.	Pb (ppm)	30	20	28
18.	C: N ratio	10.8	19.2	13.44

3.2 Pot Studies

After assessing the quality of effluents water collected from Rallis India Ltd. (Ankleshwar) and United Phosphorus Ltd., (Vapi), the same were tested for its practical utility through pot experiment to study its effect on crop yield, nutrient content and soil properties. Pot experiment was conducted in earthen pots with 14 kg soil for testing direct and cumulative effects on onion and fodder maize, respectively. Analyses of diluted (Rallis India Ltd., and United Phosphorus Ltd.) effluents water along with canal water are given in table 2.

3.2.1 Pot experiment -I : direct effect

The first pot experiment was conducted with onion as test crop to find out the feasibility of curtailing fertilizer use when irrigated with diluted effluent water. The details of technique adopted for this experiment are given below.

3.2.2 Description of soil

The soil used belongs to Jalalpur series of Typic Chromustert predominated with smectite type of clay minerals, particularly montmorillonite. Soil was medium in organic carbon, marginal in available phosphorus and sufficient in available potash. Some important physico-chemical properties of the surface soil are given in table 4.

3.2.3 Experimental details

i) Treatments

1. Canal water + recommended dose of NPK (RDF)-- NW +100
2. Rallis effluents (200 times diluted) – R+0
3. Rallis effluents (200 times diluted) + 50 % RDF--R+50
4. Rallis effluents (200 times diluted) + 75 % RDF--R+75

5. Rallis effluents (200 times diluted) + 100 % RDF--R+100
6. United Phosphorus Limited (UPL) effluents (200 times diluted) --U+O
7. UPL effluents (200 times diluted) + 50 % RDF--U+50
8. UPL effluents (200 times diluted) + 75 % RDF--U+75
9. UPL effluents (200 times diluted) + 100 % RDF--U+100
10. Canal water + no fertilizer – NW+O

ii) Test crop : onion

iii) Variety : pusa red

iv) Design : completely randomized design

v) Replication : four

vi) Recommended dose of fertilizer: 125-50-50 kg ha^{-1} or 55.8-9.75- 18.60 ppm N P K

vii) Date of transplanting : 15/12/99

viii) Date of harvesting : 14/4/2000

Table 4. **Important physico-chemical characteristics of the experimental soil**

Sr.No.	Characteristic	Method employed	Under pot study	Under field study (0-22.5cm)
A	Physical			
I	Particle size distribution	International Pipette (Piper, 1956)		
a)	coarse sand (%)		0.65	0.56
b)	fine sand (%)		11.10	26.95
c)	silt (%)		19.90	14.45
d)	clay (%)		67.20	58.10
II	Texture		Clayey	Clayey
III	Water stable aggregate (%) > 0.25 mm	Wet sieving (Yoder, 1937)	--	72.58
IV	Bulk density (Mg m^{-3})	Clod method (Dewis and Freitas, 1984)	--	1.48
B	Chemical			
1.	pH (1:2.5, soil: water)	Potentiometry (Jackson, 1973)	8.17	8.30
2.	EC (1:2.5, soil: water) dSm^{-1}	Salt bridge (Jackson, 1973)	0.31	0.15
3.	Organic carbon (%)	Walkley and Black's titration (Jackson, 1973)	0.63	0.39
4.	Total N (%)	Kjedahl's distillation (Jackson, 1973)	0.041	0.038

5. Available N (ppm)	Alkaline permaganate (Subbiah and Asija,1956)	105	87
6. Available P (ppm)	$NaHCO_3$ extractable (Olsen *et al.*,1954)	5.01	5.65
7. Available K (ppm)	Neutral N NH_4OAC (Jackson, 1973)	225	208
8. Available S (ppm)	Heat soluble (Williams and Stainbergs, 1959)	8.90	9.30
9 Exchangeable cations (C mol (P^+) Kg^{-1}			
a) Ca	Neutral N NH_4OAC (Chapman, 1965)	32.00	31.50
b) Mg	-do-	13.80	14.40
c) K	-do-	0.56	0.60
d) Na	-do-	1.80	1.95
10. DTPA extractable cations (ppm)	Atomic absorption spectrophotometry (Lindsay and Norvell, 1978)		
Fe (ppm)		8.78	9.33
Mn (ppm)		15.40	14.10
Zn (ppm)		0.96	0.51
Cu (ppm)		3.44	2.08
Pb (ppm)		1.06	0.84
Cd (ppm)		0.06	0.07
Ni (ppm)		0.78	0.74
Co (ppm)		0.68	0.84

3.2.4 Experimental techniques

Forty pots each of which was filled with 14 Kg soil. The fertilizer nutrients, N, P, and K were added through $(NH_4)_2SO_4$, $Ca(H_2PO_4)_2$ and KCl, respectively. 100 per cent of P and K and 50 per cent of N were applied as basal. After mixing fertilizer thoroughly, the soil of these pots were brought to field capacity by adding known volume of water and were allowed to equilibrate for two days and then 25 days old 5 seedlings were transplanted in each pot.

The crop was initially irrigated with normal water for establishment. Thereafter, the crop was irrigated regularly at an interval of 2 to 3 days with diluted effluents water. Remaining N was given in two splits viz., 25 per cent each at 3 and 6 weeks after transplanting. Crop was harvested at maturity. Fresh and dry weight of bulb and leaves of onion were recorded for each pot. The plant and soil samples from each pot were taken after harvest of the crop for chemical analysis.

3.2.5 Pot experiment – II : cumulative effect

The second pot experiment was carried out in the same pots subsequently, after first experiment to study the cumulative effect of diluted effluents water on growth of fodder maize as test crop, and soil properties.

3.2.6 Experimental details

i) Treatments : same as first pot experiment.

ii) Test crop : fodder Maize.

iii) Variety : Ganga safed – 2.

iv) Design : completely randomized design

v) Replication : four

vi) Recommended dose of fertilizer :

120-60-0 N : P_2O_5 : K_2O kg ha^{-1}

(53.57 – 11.70 –0 : N: P: K ppm)

vii) Date of sowing : 28/4/2000

viii) Date of harvesting : 28/6/2000

3.2.7 Experimental techniques

After harvesting onion crop a representative soil sample was collected. 100 per cent dose of P and 50 per cent N was applied as basal through $(NH_4)_2SO_4$ and Ca $(H_2PO_4)_2$. After mixing fertilizer thoroughly, the pots were brought to field capacity by adding known volume of water and were allowed to equilibrate for two days. Twenty seeds of fodder maize Ganga safed-2 were dibbled at 1 cm depth in each pot. The germination was almost completed within 7 days. The plants were thinned to 14 after a period of 7 days from the date of full germination.

The crop was initially irrigated with normal canal water for establishment. Thereafter the crop was irrigated with effluents water regularly at an interval of 1 to 2 days. Remaining 50 per cent N was applied at 30 days after sowing. The crop was harvested at initiation of tasseling. The green and dry fodder yield per pot was recorded. The plant and soil samples from each pot were taken after harvest of the crop for chemical analysis.

3.3 Field studies

After studying the physico-chemical properties of different solid wastes, the pressmud, biocompost and biological sludge were tested for practical utility through field experiments. Some of the properties of the solid wastes used in experiment are given in table 3.

3.3.1 Field experiment – I : direct effect

The first field experiment was conducted to ascertain the possibility of saving N, P and K fertilizer through use of solid waste. For this, different solid wastes were applied to field crop as per the treatment. Cabbage crop was grown as test crop. The techniques adopted for this are described in details as below.

3.3.2 Description of soil

The soil used belongs to Jalalpur series of Typic Chromusterts, predominated with smectitic type of clay minerals particularly montmorillonite (Kaswala and Deshpande, 1983). Some of the important physico-chemical properties of the surface soil (0-22.5 cm) are given in table 4. The soil was clayey in texture and normal without any salinity and sodicity problem. It was low in organic carbon, marginal in available phosphorus and sufficient in available potash.

3.3.3 Experimental details

a) Treatments

T_1 = Recommended dose of fertilizer (RDF) – control.

T_2 = Biological sludge (BS) @ 2.5 t ha^{-1} plus 100 per cent RDF

T_3 = Biological sludge (BS) @ 5 t ha^{-1} plus 100 per cent RDF

T_4 = Farm yard manure (FYM) @ 5 t ha^{-1}plus 100 per cent RDF

T_5 = Pressmud (PM) @ 5 t ha^{-1} plus 100 per cent RDF

T_6 = Biocompost (BC) @ 5 t ha^{-1} plus 100 per cent RDF

T_7 = Biological sludge (BS) @ 2.5 t ha^{-1} plus 50 per cent RDF

T_8 = Biological sludge (BS) @ 5 t ha^{-1} plus 50 per cent RDF

T_9 = FYM @ 5 t ha^{-1} plus 50 per cent RDF

T_{10}= Pressmud (PM) @ 5 t ha^{-1} plus 50 per cent RDF

T_{11}= Biocompost (BC) @ 5 t ha^{-1} plus 50 per cent RDF

b) Test crop : cabbage

c) Design : RBD

d) Replication : four

e) Plot size : gross 4.5 x 2.7 m^2

net 3.6 x 1.8 m^2

f) Spacing : 45 x 45 cm

g) Recommended fertilizer dose :

75-37.5-37.5 N : P_2O_5 : K_2O kg ha^{-1}

h) Date of transplanting : 01/11/99

i) Date of harvesting : 05/1/2000, 17/1/2000, 27/1/2000, 8/2/2000

3.3.4 Experimental techniques

The experiment was conducted in field on cabbage crop at soil and water management farm, Navsari with experimental details as given in section 3.3.3. The biological sludge, FYM, pressmud, biocompost and in - organic fertilizer were applied on dry weight basis as indicated in the treatment details. The whole quantity of phosphorus and potassium was applied as basal dose through single super phosphate and muriate of potash, respectively. Basal dose of 50 % N was applied through ammonium sulphate and remaining was applied through urea at 30 days after transplanting. The irrigation was given regularly as and when required. The other agronomic practices like interculturing, hand weeding and plant protection measures were carried out as an when required for the crop up to maturity. The cabbage head was harvested at maturity. At harvesting, representative samples of cabbage from each of plot and yield were recorded separately.

3.3.5 Field experiment-II : residual effect

The second field experiment was conducted on same plot for ascertaining the residual effect of first experiment treatment. For this summer groundnut crop was grown as test crop. The techniques adopted for this are described in details as below.

3.3.6 Experimental details

a) Plot size : gross - 4.5 x 2.7 m^2

net – 3.5 x 2.1 m^2

b) Spacing : 30 cm between two rows.

c) Fertilizer dose : 25-0-0 N : P_2O_5 : K_2O kg ha^{-1}

d) Seed rate : 100 kg ha^{-1}

e) Date of sowing : 21/2/2000

f) Date of harvesting : 6/6/2000

3.3.7 Experimental techniques

The whole quantity of N was applied as basal dose through ammonium sulphate. The irrigation was given regularly as an when required. The other agronomic practices like, hand weeding, inter culturing were followed as per the recommendation. At harvesting representative sample of pod and haulm were collected from each of net plot and number of mature pods plant^{-1} and pod yield and haulm yield were recorded separately.

3.4 Collection and preparation of soil samples

After the harvest of the crop, the soil in each pot was thoroughly mixed and representative sample was collected. Soil sample from each plot of field experiment was also collected. A separate undisturbed soil clod of suitable size was also collected from each plot for determination of bulk density. Then soil samples were brought to the laboratory, air-dried and powdered with a wooden mortar. It was passed through 2 mm sieve and mixed thoroughly and necessary precautions were taken to avoid any contamination from extraneous sources. The samples were analyzed for different nutrients following standard methods as given in table 3.

3.5 Plant analysis

The harvested portion of the crops were first washed with large quantity of tap water to remove the soil and dust particles. Afterwards they were washed with distilled water twice as the materials were to be analyzed for major, micronutrient and heavy metal. The heads, bulbs pods, shoots and leaves were cut with the help of stainless steel cutter and were air-dried first and subsequently dried in oven at 65 ^{0}C. Then all samples of each crop were powdered with the help of stainless steel grinder.

The concentration of elements viz., N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, Pb, Cd, Co and Ni were determined. For the determination of secondary and micronutrient and heavy metal acid extract was prepared by digesting 0.5 gm sample with binary acid mixture of HNO_3 and $HClO_4$ in the proportion of 10 : 4, making the final volume to 100 ml.

The chemical methods followed for the estimation of different constituents are given below.

1.	Nitrogen	-	Kjeldahl's method (Jackson, 1973)
2.	Phosphorus	-	Vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973)
3.	Potassium	-	Flame photometric determination (Jackson, 1973)
4.	Calcium and magnesium	-	Versenate titration method (Jackson, 1973)
5.	Sulphur	-	Turbidometry method (Jackson, 1973)
6.	Micronutrient- and Heavy metal		The estimation of Fe, Mn, Zn, Cu, Pb, Ni, Cd and Co were carried out by using Atomic absorption spectrophotometer (Perkin Elmer Model-3110)

3.6 Uptake of nutrients

The uptake of nutrients by different crops was calculated by using following formula.

(1) Nutrient uptake (mg pot^{-1}) $= \dfrac{\text{content (\%)} \times \text{yield (g pot}^{-1}) \times 1000}{100}$

(2) Nutrient uptake (kg ha^{-1}) $= \frac{\text{content (\%) x yield (kg ha}^{-1})}{100}$

3.7 Statistical analysis

The data collected from various aspect of studies were subjected to statistically analysis as per the method suggested by Gomez and Gomez (1984), for interpretation of the results.

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

The results obtained from pot and field experiments with respect to yield and its attributing parameters, nutrient content and uptake, physico-chemical characteristics of soil, available major and micronutrient as well as heavy metal contents in soil and plant are described in this chapter under following subtitle.

4.1 Feasibility study of fertilizer reduction through effluents water

Based on the dilution (200 times) of both the effluents water analysis, pot experiments were conducted to explore the feasibility for reduction in the fertilizer dose to the crops when irrigated with the 200 times diluted with effluents water. For this, as mentioned before, the experiments were conducted with two crops viz., direct effect on onion crop and cumulative effect on fodder maize. The relevant results obtained are presented below.

4.1.1 Direct effect on onion crop

4.1.1.1 Dry matter yield

Both the fresh and dry yields of onion bulbs were significantly affected due to different levels of fertilizer as well as the quality of irrigation water (Table 5). With increasing levels of fertilizer in conjunction with both effluent water treatments, there was increase in the yield. It varied from 110 g pot^{-1} at NW+O to 320 g pot^{-1} at R+100 in case of fresh yield. The corresponding figures for dry yields were 13.63 and 39.40 g pot^{-1}. At the same level of recommended dose of fertilizer, the yield with both effluent water was significantly higher when compared to normal water. Applied fertilizer response was obtained up to R+75 treatment in case of Rallis India Ltd. (RIL) effluents. Whereas, in case of United Phosphorus Ltd. (UPL) effluents, the response was up to U+100 treatment. It is also interesting to note that the yield obtained with

Table 5. Direct effect of diluted industrial effluents and graded fertilizer levels on fresh and dry weight of onion bulb and leaves

Treatments	Bulb (g pot^{-1})		Leaves (g pot^{-1})	
Effluent+RDF (%)	Fersh	Dry	Fersh	Dry
NW+100	239.75	29.66	67.50	8.27
R+0	202.50	25.12	56.25	6.92
R+50	241.25	29.94	75.00	9.17
R+75	295.00	36.69	97.50	11.89
R+100	320.00	39.40	98.75	11.98
U+0	185.00	22.92	41.25	5.09
U+50	218.75	27.14	62.50	7.68
U+75	227.50	28.26	70.00	8.56
U+100	285.00	35.49	92.50	11.26
NW+0	110.00	13.63	28.75	3.62
S.Em ±	11.42	1.45	3.62	0.44
C.D at 5%	30.90	4.17	10.44	1.27

50 per cent recommended dose alongwith effluents water were statistically the same as that obtained with application of 100 per cent RDF and irrigated with normal water.

Similar to bulb, the yield of leaves also increased with increase in the fertilizer doses. However, the yield obtained at 100 per cent recommended dose with normal water and 50 per cent recommended dose with both effluents were at par. Though, the yield obtained at R+100 and U+100 at par between themselves, yet, significantly superior to NW+100 (100 per cent RDF plus normal water irrigation).

4.1.1.2 Nutrient content and uptake

4.1.1.2.1 Major nutrients

There were significant differences in the N content of bulb due to fertilizer levels and effluents water as source of irrigation water (Table 6). As the per centage of fertilizer dose increases, there was increase in the N content in bulb with both the effluent treatments. The content recorded at R+100 (2.16 %) and U+100 (2.12 %) was at par but significantly better than that of NW+100 (1.90 %). Significantly minimum value (1.10 %) was recorded at NW+O followed by at UPL effluents and RIL effluents irrigation without fertilizer application (U+0 and R+O).

The P content in different treatments varied from 0.15 per cent in normal water with no fertilizer treatment (NW+O) to 0.28 per cent in RIL effluents with 100 per cent fertilizer treatment (R+100), but latter treatment was statistically at par with U+100 (UPL effluents irrigation + 100 per cent RDF). At the same level of recommended dose (100 per cent RDF), application with either of the quality of the irrigation water the contents were at par. The content of P was statistically same with respect to same fertilizer levels, irrespective to quality of irrigation water except at no fertilizer application.

Table 6. Direct effect of diluted industrial effluents and graded fertilizer levels on major nutrient content and uptake by onion bulb

Tretments	Content (%)			Uptake (mg pot^{-1})		
Effluent +RDF (%)	N	P	K	N	P	K
NW+100	1.90	0.24	1.60	563	70.52	474
R+0	1.78	0.21	1.45	444	52.34	363
R+50	2.01	0.21	1.62	601	71.35	485
R+75	2.08	0.26	1.71	762	94.71	626
R+100	2.16	0.28	1.80	843	108.97	706
U+0	1.75	0.19	1.40	401	43.18	320
U+50	1.96	0.22	1.58	532	59.72	428
U+75	2.02	0.23	1.67	570	65.16	472
U+100	2.12	0.24	1.76	751	85.12	624
NW+0	1.10	0.15	1.10	149	20.20	149
S.Em±	0.02	0.02	0.03	24	3.75	19
C.D at 5%	0.07	0.05	0.08	70	10.83	54

The K content was maximum (1.80 %) in RIL effluents water application with 100 per cent RDF and it was statistically same with U+100 (1.76 %). The content recorded at 100 per cent fertilizer dose with normal water was at par with 50 per cent fertilizer doses with both the effluents water treatment.

The N uptake at the 100 per cent fertilizer dose with normal irrigation water was 563 mg pot^{-1} (Table 6), which was statistically the same as that obtained with 50 per cent fertilizer dose with RIL effluents irrigation (601 mg pot^{-1}) and UPL effluents irrigation (532 mg pot^{-1}). But these values were significantly lower than that recorded with RIL and UPL effluents irrigation alongwith 100 per cent fertilizer dose. Further, the N uptake recorded at normal water irrigation with no fertilizer was significantly lower than that recorded at both of the effluents water irrigation with no fertilizer treatment.

The P uptake was also of the same trend as that of N and maximum removal of P was recorded in RIL effluents irrigation with 100 per cent fertilizer dose (108.97 mg pot^{-1}). The treatments NW+100, R+50 and U+75 remained at par and the removal of P in these treatments was statistically lesser than that of R+100 and U+100 treatments.

The K removal was lowest at no fertilizer with normal water irrigation (149 mg pot^{-1}) and increased significantly with every level of fertilizer application in both the effluents irrigation. The maximum uptake of K was recorded at R+100 (706 mg pot^{-1}). The uptake at 100 per cent RDF with normal water irrigation (474 mg pot^{-1}), was at par with R+50 (485 mg pot^{-1}) and U+50 (428 mg pot^{-1}).

The N content of the leaves varied from 0.39 per cent (NW+O) to 0.92 per cent (R+100). With successive increase in the fertilizer dose, there was increase in the N content in leaves in both the effluents water treatments

(Table 7). With the same level of fertilizer dose (100 per cent recommended dose) the N contents in leaves at R+100 and U+100 were significantly more as compared to NW+100. However, the N content at NW+100 was statistically at par with 50 per cent RDF and irrigated with either RIL effluents or UPL effluents water.

The trend of P content pattern in leaves was almost same as that of N content pattern. But the value between R+100 (0.089 %) and U+100 (0.080 %) were statistically differ. There was no significant difference between the P contents recorded at R+50 (0.076 %) and NW+100 (0.078 %) treatments.

The K contents in the leaves was maximum (1.02 %) at R+100 followed by U+100 (0.96 %) and differed significantly from values recorded at R+75 and U+75 treatments. Similarly, the values of K among NW+100 (0.89 %), R+50 (0.89 %) and U+50 (0.85 %) were statistically same but significantly differed from R+O (0.74 %) and U+O (0.70 %).

The removal of N, P and K by the leaves followed identical pattern. For N, P and K elements the removal was highest (110.04 mg N pot^{-1}, 10.65 mg P pot^{-1} and 121.9 mg K pot^{-1}) at R+100 treatments. Which were significantly higher than the corresponding values at any treatments. With the increase in the fertilizer dose, there was significant increase in the uptake of N, P and K nutrients in both the effluents irrigation. The removal of N and K at R+50 (74.53 mg N pot^{-1} and 81.36 mg K pot^{-1}) was significantly higher than that of NW+100. The latter treatment removed more N and K as compared to U+50 (58.88 mg N pot^{-1} and 65.04 mg K pot^{-1}). The uptake of P was statistically same as obtained at R+50, U+50 and NW+100.

4.1.1.2.2 Secondary nutrients

The Ca and Mg content in bulb did not differ significantly due to different treatments (Table 8). Though the Ca content in leaves found to be

Table 7. Direct effect of diluted industrial effluents and graded fertilizer levels on major nutrients content and uptake by onion leaves

Treatments	Content (%)			Uptake (mg pot^{-1})		
Effluent +RDF (%)	N	P	K	N	P	K
NW+100	0.80	0.078	0.89	65.83	6.43	73.43
R+0	0.73	0.068	0.74	50.23	4.68	50.97
R+50	0.81	0.076	0.89	74.53	6.95	81.36
R+75	0.86	0.081	0.94	101.60	9.62	111.4
R+100	0.92	0.089	1.02	110.04	10.65	121.9
U+0	0.69	0.062	0.70	34.91	3.14	35.54
U+50	0.77	0.071	0.85	58.88	5.43	65.04
U+75	0.80	0.074	0.90	67.73	6.30	76.59
U+100	0.88	0.080	0.96	98.74	8.99	107.8
NW+0	0.39	0.05	0.50	13.85	1.80	18.12
S.Em±	0.03	0.002	0.02	2.37	0.26	2.70
C.D at 5%	0.07	0.006	0.07	6.82	0.75	7.79

Table 8. Direct effect of diluted industrial effluent and graded fertilizer levels on secondary nutrient content and uptake by onion bulb.

Treatments	Content (%)			Uptake (mg pot^{-1})		
Effluent+RDF (%)	Ca	Mg	S	Ca	Mg	S
NW+100	0.42	0.29	0.26	124	85.6	77.0
R+0	0.37	0.27	0.24	92.4	67.5	60.8
R+50	0.40	0.28	0.26	119.1	83.2	77.5
R+75	0.43	0.29	0.28	157.2	105.4	101.9
R+100	0.46	0.30	0.30	178.3	116.2	115.8
U+0	0.36	0.26	0.25	74.2	59.0	57.0
U+50	0.38	0.27	0.30	103.0	72.9	81.3
U+75	0.40	0.28	0.37	112.4	78.9	104.2
U+100	0.44	0.29	0.39	154.1	100.9	137.7
NW+0	0.33	0.25	0.13	44.7	33.7	17.5
S.Em±	0.03	0.02	0.02	4.69	4.09	4.06
C.D at 5%	NS	NS	0.05	13.5	11.8	11.7

significant (Table 9). No fertilizer treatments (NW+O) were recorded significantly lower Ca content in leaves than that of any other treatments, though R+O and U+O remained at par between themselves but significantly superior to NW+O. Mg content in leaves as like the bulb was also found non significant. The contents of S in both bulb and leaves differed significantly due to different treatments. The S content in the bulb varied from 0.13 per cent at NW+O to 0.39 per cent at U+100, both of them differed significantly between themselves. But treatment NW+100 (0.26 %), R+50 (0.26 %) and U+50 (0.30%) were statistically at par with one-another. Similar types of accumulation of S was observed in case of leaves. In this case the U+O (0.46 %) was statistically same as obtained with NW+100 (0.49 %) and R+50 (0.50 %).

The uptake pattern of Ca and Mg in onion bulb as affected by different treatments was more or less similar. The Ca and Mg removal by bulb were statistically maximum at R+100 (178.3 mg Ca pot^{-1} and 116.2 mg Mg pot^{-1}). The values were minimum at NW+O. Statistically the same amount of these two nutrients were observed to be removed at N+100, R+50 and U+75. The S uptake by bulb varied widely ranging from 17.5 mg pot^{-1} at NW+O to 137.7 mg pot^{-1} at U+100. With every increase in the fertilizer dose there was significant increase in the S uptake in both the effluents irrigation treatments. At the same levels of fertilizer (100 per cent recommended dose) the uptake at R+100 and U+100 were significantly more as compared to NW+100. The removal of S at the latter treatment was statistically same as that recorded at R+50 and U+50 treatments.

The uptake of Ca and Mg by the leaves as affected by different treatments was almost similar. With the same level of fertilizer (100 per cent RDF) the removal of Ca and Mg was more at R+100 and U+100 as compared to NW+100. The S uptake was statistically highest (73 mg pot^{-1}) at U+100 and the

Table 9. Direct effect of diluted industrial effluents and graded fertilizer levels on secondary nutrient content and uptake by onion leaves

Treatments	Content (%)			Uptake (mg pot^{-1})		
Effluent+RDF (%)	Ca	Mg	S	Ca	Mg	S
NW+100	1.40	0.59	0.49	116	49	40
R+0	1.34	0.60	0.42	92	41	29
R+50	1.41	0.60	0.50	129	55	46
R+75	1.43	0.61	0.51	169	72	60
R+100	1.45	0.62	0.55	173	74	66
U+0	1.32	0.58	0.46	67	29	23
U+50	1.39	0.58	0.50	107	45	38
U+75	1.40	0.59	0.59	120	51	50
U+100	1.42	0.61	0.65	160	68	73
NW+0	1.15	0.57	0.26	42	21	9
S.Em±	0.04	0.02	0.01	5	1.75	1.52
C.D at 5%	0.10	NS	0.04	14	5	4

lowest (9.06 mg pot^{-1}) at NW+O. Though there was tendency for regular significant increase, with increases in the fertilizer dose in both of the effluents water irrigation.

4.1.1.2.3 **Micronutrients**

The results regarding concentration of Fe, Mn, Zn and Cu in onion bulb and leaves are reported in table 10 and 11. Concentration of Fe in bulb and leaves varied significantly due to effluents water application and fertilizer doses. Significantly higher concentration of Fe in bulb was recorded with R+100 treatment (76.35 mg kg^{-1}) which was at par with R+75 (77.15 mg kg^{-1}) and R+50 (74.0 mg kg^{-1}) treatments. The concentration of Fe at U+100, U+75 and U+50 were 68.48, 66.50 and 67.38 mg kg^{-1}, respectively. These all the values recorded with RIL and UPL effluents water along with 50, 75 and 100 per cent recommended doses were significantly higher than that of treatment of normal water plus 100 per cent recommended dose (61.23 mg kg^{-1}). As like the bulb, the concentration of Fe in leaves was also higher under the treatment of either RIL or UPL effluents water irrigation alongwith any dose of fertilizer. The concentration of Mn in bulb and leaves were also higher under both effluents irrigation treatments as compared to normal water irrigation (36.48 mg kg^{-1}).The maximum was recorded at R+75 treatments in case of bulb (60.20 mg kg^{-1}) and R+100 treatments in case of leaves (60.60 mg kg^{-1}). In case of Zn content in bulb, it varied from 13.55 mg kg^{-1} at NW+O to 34.73 mg kg^{-1} at R+50 treatment. While in leaves it ranged from 14.40 mg kg^{-1} at N+O to 42.23 mg kg^{-1} at R+100 treatments. Though Zn concentration was higher under RIL effluents irrigation as compared to UPL effluents irrigation both in bulb and leaves. With respect to Cu content in bulb and leaves, there was no significant difference between the content recorded at 100 per cent RDF alongwith either RIL (13.25 13.98 mg

Table 10. Direct effect of diluted effluents and graded fertilizer levels on micronutrient content and their uptake by onion bulb

Treatments	Content (mg pot^{-1})				Uptake (mg pot^{-1})			
Effluent +RDF (%)	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
NW+100	61.23	36.48	23.38	11.93	2.28	1.09	0.70	0.33
R+0	58.10	41.32	22.50	10.43	1.85	1.04	0.56	0.26
R+50	74.00	55.98	34.73	13.83	2.75	1.67	1.04	0.42
R+75	77.15	60.20	34.15	13.44	3.21	2.22	1.26	0.50
R+100	76.35	57.20	34.53	13.25	3.53	2.26	1.37	0.52
U+0	50.90	38.70	21.50	10.55	1.61	0.89	0.48	0.24
U+50	67.38	50.78	28.44	12.70	2.21	1.38	0.78	0.35
U+75	66.50	47.95	29.18	12.88	2.29	1.36	0.82	0.36
U+100	68.48	50.15	28.25	13.08	2.93	1.79	1.02	0.48
NW+0	20.45	10.35	13.55	6.13	0.40	0.14	0.198	0.05
S.Em ±	2.67	2.14	2.03	1.09	0.15	0.11	0.09	0.04
CD at 5%	7.71	6.17	5.86	3.16	0.42	0.33	0.27	0.11

Table 11. Direct effect of diluted effluents and graded fertilizer levels on micronutrient content and their uptake by onion leaves

Treatments	Content (mg kg^{-1})				uptake (mg pot^{-1})			
Effluent+RDF (%)	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
NW+100	76.53	43.05	27.20	12.65	0.63	0.36	0.23	0.10
R+0	73.63	44.30	26.58	12.15	0.51	0.31	0.19	0.08
R+50	91.95	58.85	41.60	14.38	0.85	0.54	0.387	0.13
R+75	87.9	58.75	41.90	14.23	1.06	0.70	0.50	0.17
R+100	89.48	60.60	42.23	13.98	1.07	0.73	0.51	0.17
U+0	70.03	40.13	25.33	10.55	0.36	0.21	0.13	0.06
U+50	81.42	49.38	33.75	13.15	0.63	0.38	0.26	0.10
U+75	80.90	49.90	33.93	12.98	0.69	0.42	0.28	0.11
U+100	82.93	49.95	33.98	13.03	0.94	0.56	0.39	0.15
NW+0	29.62	14.73	14.40	6.88	0.11	0.06	0.05	0.02
S.Em ±	3.14	2.90	1.86	1.07	0.06	0.03	0.02	0.01
CD at 5%	9.08	8.39	5.37	3.09	0.16	0.10	0.07	0.04

kg^{-1}) or UPL (13.08 and 13.03 mg kg^{-1}) and 100 per cent RDF plus normal water irrigation (11.93 and 22.65 mg kg^{-1}).

The data reported in table 10 and 11 also indicate the uptake of Fe, Mn, Zn and Cu by onion bulb and leaves.

In case of bulb, Fe uptake varied considerably, as it ranged from 0.40 mg pot^{-1} with NW+O to as high as 3.53 mg pot^{-1} with R+100. At the same level of fertilizer dose (100 per cent RDF) the Fe removal registered at R+100, U+100 and NW+100 were 3.53, 2.93 and 2.28 mg pot^{-1}, respectively. It is also seen that the removal of Fe at NW+100 was practically remained same as that recorded under 50 per cent RDF alongwith either RIL or UPL effluents. Almost, similar pattern of Fe uptake was noted in case of leaves. The uptake pattern of Mn by leaves and bulb was almost similar. The maximum uptake of Mn was recorded at R+100 (2.26 and 0.73 mg pot^{-1}) which was significantly higher than that of any other treatments. The Mn removal was slightly higher under RIL effluents. In case of Zn uptake of bulb, the maximum was registered under R+100 (1.37 mg pot^{-1}) followed by R+75 (1.26 mg pot^{-1}) with respect to RIL effluents while, 1.02 and 0.82 mg pot^{-1} Zn was removed under the treatment effect of U+100 and U+75. The removal of Zn at R+50 (1.04 mg pot^{-1}) was much higher than that recorded at U+50 (0.78 mg pot) and NW+100 (0.70 mg pot). The pattern of Zn removal in leaves was almost similar to that of bulb. The uptake pattern of Cu was almost similar to that of Zn uptake. Both in bulb and leaves the maximum removal was recorded either with RIL or UPL effluents irrigation alongwith inorganic fertilizer application. The total removal of Cu at NW+100, U+50 and R+50 were remained practically same.

4.1.1.2.4 Heavy metal content

The concentration of Ni, Pb, Cd and Co in onion bulb and leaves are presented in table 12. The data revealed that the concentration of all the heavy

Table 12. Direct effect of diluted effluents and graded fertilizer levels on some heavy metal content in onion

Treatments	Onion bulb (mg kg^{-1})				Onion leaves (mg kg^{-1})			
Effluent+RDF (%)	Ni	Pb	Cd	Co	Ni	Pb	Cd	Co
NW+100	0.627	0.819	0.014	0.76	0.722	0.970	0.018	1.130
R+0	0.630	0.823	0.015	0.715	0.728	0.971	0.019	1.00
R+50	0.635	0.823	0.016	0.780	0.731	0.975	0.018	1.155
R+75	0.633	0.825	0.015	0.765	0.733	0.973	0.018	1.160
R+100	0.631	0.822	0.015	0.780	0.734	0.973	0.019`	1.155
U+0	0.629	0.820	0.015	0.765	0.731	0.973	0.018	1.075
U+50	0.629	0.827	0.015	0.830	0.731	0.973	0.018	1.210
U+75	0.628	0.825	0.014	0.830	0.728	0.972	0.018	1.210
U+100	0.629	0.826	0.015	0.845	0.728	0.968	0.018	1.205
N+0	0.197	0.264	ND	0.410	0.227	0.303	ND	0.523
S.Em ±	0.005	0.006	0.002	0.036	0.005	0.005	.0009	0.033
CD at 5%	0.015	0.016	0.004	0.103	0.015	0.014	0.002	0.095

metals determined in the different treatments was statistically same except, the treatment of no fertilizer application alongwith normal water (NW+O), which accumulated very low concentration of metals.

4.1.1.3 **Soil Study**

4.1.1.3.1 **Physico-chemical properties**

The Physico-chemical properties like; soil reaction, electrical conductivity and organic carbon status of the soil were affected significantly due to different quality of irrigation water (Table 13).

The soil reaction value varied from 7.71 at 100 % RDF with RIL effluents to 8.19 at no fertilizer with normal water irrigation. In case of RIL effluents irrigation, the soil reaction value varied from 7.79 (R+0) to 7.71 (R+100) and both value found statistically at par between themselves. Similarly in UPL effluents water irrigation the soil reaction value varied from 8.00 (U+O) to 7.95 (U+100) and also found non-significant between themselves. Though, soil reaction value after 100% RDF with normal water irrigation (8.13) was significantly higher than any dose of fertilizer with both effluents irrigation.

The EC (Electrical conductivity) value increased significantly with the usage of both effluents water when compared to normal water. In RIL effluents water irrigation the EC value at R+O (1.22 dSm^{-1}) significantly differed from R+100 (1.39 dSm^{-1}) and R+75 (1.34 dSm^{-1}). Similarly in UPL effluents the same trend was also observed. Irrespective of fertilizer level, the EC value after irrigating with RIL effluents was significantly lower than that noted after UPL effluents irrigation.

The organic carbon content increased significantly with both of the effluents water treatments when compared to normal water irrigation (0.71 %). Among the different fertilizer levels with RIL effluents water, though the maximum (1.05 %) was observed at 100 % RDF it was at par with 50 % RDF.

Table 13. Direct effect of diluted industrial effluents and graded fertilizer levels on physico-chemical properties of the soil

Treatments	Physico-chemical properties of soil		
Effluent +RDF (%)	pH (1:2.5)	EC (dSm^{-1})	Organic carbon (%)
NW+100	8.13	0.67	0.71
R+0	7.79	1.22	0.92
R+50	7.76	1.30	0.96
R+75	7.75	1.34	0.98
R+100	7.71	1.39	1.05
U+0	8.00	2.14	0.95
U+50	7.99	2.16	0.96
U+75	7.95	2.23	0.99
U+100	7.95	2.23	1.01
NW+0	8.19	0.35	0.70
S.Em.±	0.03	0.04	0.04
C.D at 5%	0.09	0.11	0.11

In case of UPL, effluents, there was no significant difference observed due to different levels of fertilizer.

4.1.1.3.2 Available major nutrients

The available N status jumped from 102 ppm with normal water with no fertilizer to 436 ppm after RIL effluent irrigation with 100 per cent recommended fertilizer (Table 14). With the same level of fertilizer dose (100 per cent recommended) the value at NW+100 (144 ppm) was significantly lower than observed either with R+100 (436 ppm) or U+100 (170 ppm). In general the accumulation of available N was more after RIL effluents irrigation as compared to UPL effluents irrigation. In both the effluents irrigation, there was tendency for increase in the available N values, with every increase in fertilizer dose.

The available P content in soil varied from 4.32 ppm in no fertilizer with normal irrigation to 13.24 ppm with 100 per cent fertilizer doses in conjunction with RIL effluent. However the later treatment was significantly superior to U+100 (8.82 ppm). The available P increased numerically with increase in the fertilizer levels in both the effluents water treatments. There was no significant difference between the treatment of NW+100 (6.36 ppm) and U+50 (6.65 ppm).

The available K was the highest at U+100 (332 ppm) and the lowest was recorded at NW+O (219 ppm). The available K recorded at NW+100 (274 ppm), R+75 (255 ppm) and R+100 (273 ppm) were statistically at par with each other whereas K noted at NW+100 was significantly lower than that noted after irrigating with UPL effluents along with applying inorganic fertilizer.

4.1.1.3.3 DTPA extractable micronutrients

The mean available Fe values varied from 8.52 mg kg^{-1} in NW+O to 13.13 mg kg^{-1} in R+75 (Table 15), both of them significantly differed between themselves. Each of the fertilizer level with either RIL or UPL effluents irrigation accumulated significantly higher content of Fe than that of normal

Table 14. Direct effect of diluted industrial effluents and graded fertilizer levels on major available nutrient status of the soil

Treatments	Available nutrients status (ppm)		
Effluent + RDF (%)	N	P	K
NW+100	144	6.36	274
R+0	403	8.01	246
R+50	412	11.21	251
R+75	425	12.16	255
R+100	436	13.24	273
U+0	163	5.88	263
U+50	170	6.65	297
U+75	168	7.36	311
U+100	170	8.82	332
NW+0	102	4.32	219
S.Em.±	9	0.33	8
C.D at 5%	26	0.97	22

Table 15. Direct effect of diluted industrial effluent and graded fertilizer levels on DTPA extractable micronutrient in soil

Treatments Effluent +RDF (%)	DTPA- extractable micro nutrients (mg kg^{-1}) Fe	Mn	Zn	Cu
NW+100	9.80	17.40	0.96	3.68
R+0	12.07	17.55	0.98	3.72
R+50	12.73	19.22	1.21	3.68
R+75	13.13	22.77	1.18	4.33
R+100	12.92	19.32	1.23	3.66
U+0	11.68	30.07	1.01	3.80
U+50	11.66	29.33	1.03	3.50
U+75	11.98	32.73	1.16	4.45
U+100	12.18	31.36	1.16	3.68
NW+0	8.52	12.05	0.93	3.45
S.Em±	0.51	1.11	0.06	0.17
C.D at 5%	1.47	3.19	0.16	0.50

water irrigation with 100 per cent RDF (NW+100) and without fertilizer (NW+O).

The maximum Mn content (22.77 mg kg^{-1}) was observed at R+75 treatment in case of RIL effluents, it was statistically superior to NW +100 treatment (17.40 mg kg^{-1}). After irrigating the crop with UPL effluent, the maximum Mn content was accumulated at U+75 followed by U+100, these treatments were significantly better than that of NW+100. Between two effluents irrigation it was observed that, Mn accumulation in the soil was more after UPL effluent irrigation as compared to RIL effluents irrigation.

After irrigating the crop with RIL effluents, the available Zn content varied from 0.98 mg kg^{-1} in no fertilizer treatment to 1.23 mg kg^{-1} with 100 per cent dose. The corresponding value for UPL effluents was 1.01 to 1.16 mg kg^{-1}. In both the effluents irrigation treatments, 100 per cent dose was statistically at par with 75 and 50 per cent dose with effluents water but all these treatments were significantly superior to NW+100 treatments (0.96 mg kg^{-1}).

In case of RIL effluents, the available Cu varied from 3.72 mg kg^{-1} (RIL effluent + no fertilizer) which was significantly lower to 4.33 mg kg^{-1} at 75 per cent doses with RIL effluents water. The value after 100 per cent dose with normal water and 50 per cent fertilizer dose with both effluents water was at par with each other. Almost similar trend was observed in case of Cu after irrigating the UPL effluents water.

4.1.1.3.4 **DTPA extractable heavy metal**

The Ni content in soil was found slightly higher after RIL effluents irrigation as compared to UPL effluents irrigation (Table 16) which varied from 0.89 mg kg^{-1} to 0.92 mg kg^{-1} in case of RIL while corresponding value for UPL effluents was 0.83 to 0.87 mg kg^{-1}. Further the value of 0.79 mg kg^{-1} at NW+100 increased to 0.92 mg kg^{-1} at R+100 and 0.87 mg kg^{-1} at U+100 treatments.

Table 16. Direct effect of diluted industrial effluents and graded fertilizer levels on DTPA extractable heavy metal in soil

Treatments Effluent + RDF (%)	DTPA extractable heavy metals status (mg kg^{-1}) Ni	Cd	Pb	Co
NW+100	0.79	0.068	1.11	0.65
R+0	0.89	0.075	1.21	0.65
R+50	0.91	0.070	1.25	0.71
R+75	0.92	0.070	1.23	0.71
R+100	0.92	0.073	1.27	0.83
U+0	0.83	0.068	1.12	0.78
U+50	0.85	0.070	1.22	0.80
U+75	0.86	0.080	1.21	0.96
U+100	0.87	0.075	1.21	0.88
NW+0	0.76	0.065	1.08	0.61
S.Em±	0.02	0.004	0.05	0.02
C.D at 5%	0.06	NS	NS	0.06

The content of Cd and Pb in soil, after harvest of onion was found to be non- significant. However, the content of Co in soil was found significant which varied from 0.61 mg kg^{-1} at NW+O to 0.96 mg kg^{-1} at U+75 treatments. The result revealed that Co content after UPL effluent irrigation was found slightly higher that of RIL effluents irrigation.

4.1.2 Cumulative effect of diluted effluents on fodder maize crop

4.1.2.1 Dry matter yield

The fresh and dry matter yield of maize fodder was 758.25 and 113.94 g pot^{-1}, respectively when 100 per cent of the dose of fertilizer was applied alongwith RIL effluents water treatment (Table 17). However, these were statistically at par with U+100 (712 g pot^{-1} and 106.80 g pot^{-1} fresh and dry matter yield) and R+75 (710.5 and 104.75 g pot^{-1} fresh and dry matter yield), respectively. The treatments viz., U+100 and R+100 also produced significantly higher yield than obtained with 100 per cent recommended dose of fertilizer and irrigated with normal water. It is interesting to see that 100 per cent of the fertilizer application with normal water irrigation produced the yield statistically same as 50 per cent recommended dose of fertilizer application with either UPL or RIL effluents irrigation. Besides, the above result data also indicated that RIL effluents irrigation responded to the extent of 50 per cent recommended whereas UPL effluents irrigation responded up to 75 per cent recommended fertilizer application.

4.1.2.2 Nutrient content and uptake

4.1.2.2.1 Major nutrients

The N content in maize fodder was maximum (2.07 %) at R+100 and this was significantly higher than the contents recorded at all other treatments except, U+100 and R+75, which were at par (Table 18). The treatments U+100, U+75 and U+50 also were at par among themselves. The contents recorded at

Table 17. Cumulative effect of diluted industrial effluents and graded fertilizer levels on fresh and dry yield of fodder maize

Treatments Effluent +RDF (%)	Fresh yield (g pot^{-1})	Dry yield (g pot^{-1})
NW+100	589.00	85.41
R+0	446.75	63.89
R+50	675.50	95.34
R+75	710.50	104.45
R+100	758.25	113.74
U+0	435.25	61.81
U+50	606.50	87.94
U+75	681.75	99.83
U+100	712.00	106.80
NW+0	151.00	20.99
S.Em±	24.79	3.63
C.D at5%	71.60	10.47

Table 18. Cumulative effect of diluted industrial effluents and graded fertilizer levels on major nutrient content and their uptake by maize fodder

Treatments Effluent +RDF (%)	Content (%)			Uptake (mg pot^{-1})		
	N	P	K	N	P	K
NW+100	1.89	0.64	1.79	1608	546	527
R+0	1.77	0.55	1.65	1129	350	1052
R+50	1.90	0.65	1.83	1804	618	1743
R+75	1.97	0.69	1.90	2057	720	1892
R+100	2.07	0.72	1.98	2350	817	2248
U+0	1.69	0.53	1.66	1044	327	1025
U+50	1.86	0.62	1.78	1631	542	1562
U+75	1.91	0.65	1.86	1905	647	1854
U+100	1.99	0.69	1.92	2120	735	2047
NW+0	1.08	0.30	1.05	226	63	220
S.Em±	0.04	0.02	0.04	48	15	52
C.D at 5%	0.13	0.04	0.11	137	42	151

R+50, U+50 and NW+100 were at par and significantly more than the no fertilizer application with either quality of effluent irrigation water.

The P content was recorded maximum with R+100 (0.72 %), which was at par with R+75 and U+100 and significantly superior to all other treatments. The content recorded at NW+O (0.30 %) was the lowest. Moreover, the treatment NW+100, R+50 and U+50 were also statistically at par to each other.

The K content of the fodder maize varied from 1.05 % in NW+0 to 1.98 % in U+100, both differing significantly. With the same level of fertilizer dose (100 % recommended dose) the K content at R+100 and U+100 was statistically at par and significantly more as compared to NW+100. There was also no significant difference between the contents recorded at R+O and U+O.

The uptake pattern of N and P by the maize fodder was almost the same .The removal of N and P by straw was maximum (2350 mg N pot^{-1} and 817 mg P pot^{-1}) at R+100. This differed significantly from all other treatments. The removal of N and P was at par at R+75 and U+100. Similarly the treatments R+50 and U+75 also practically remained the same, in respect to N and P removal. The uptake of N and P at R+50 (1804 and 618 mg pot^{-1} N and P) was significantly more than that at NW+100 (1608 mg N and 546 mg P pot^{-1}). The latter treatment was also statistically at par with U+50. The K uptake also was maximum (2248 mg pot^{-1}) at R+100. In this case, the values at U+50 (1562 mg pot^{-1}) and NW+100 (1527 mg pot^{-1}) did not differ significantly but statistically lower than that R+50. Further, the removal of K was more in both effluents irrigation with no fertilizer treatment (U+0 and R+0) as compared to normal water irrigation without fertilizer application (NW+0).

4.1.2.2.2 Secondary nutrients

The Ca content varied from 0.40 % at NW+O to 0.52 % at R+100 (Table 19). The content recorded at NW+100 (0.48 %) were at par with R+50 (0.48 %)

Table 19. Cumulative effect of diluted industrial effluents and graded fertilizer levels on secondary nutrient content and their uptake by maize fodder

Treatments	Content (%)			Uptake (mg pot^{-1})		
Effluent+RDF (%)	Ca	Mg	S	Ca	Mg	S
NW+100	0.48	0.38	0.20	406	323	170
R+0	0.44	0.37	0.16	280	235	102
R+50	0.48	0.38	0.20	454	358	189
R+75	0.50	0.38	0.20	521	395	229
R+100	0.52	0.40	0.24	587	453	272
U+0	0.43	0.36	0.18	266	222	111
U+50	0.46	0.38	0.22	400	330	191
U+75	0.47	0.38	0.25	467	378	249
U+100	0.49	0.39	0.28	522	445	297
NW+0	0.40	0.32	0.10	84	67	21
S.Em±	0.02	0.03	0.01	13	17	7
C.D at 5%	0.07	NS	0.04	36	49	21

and U+50 (0.46 %). Though with increase in fertilizer dose, there was increase in the Ca content in both the effluents irrigation, yet in most case, the adjacent fertilizer dose treatments were at par. The Mg content was not affected due to any of the treatments. The S content was higher (0.28 %) at U+100, which was at par with the values of 0.25 % recorded at U+75 and 0.24 % recorded at R+100. In this case also with increase in fertilizer dose there was increase in the S content, in most of the cases the adjacent treatments were at par.

The uptake of Ca by fodder maize was maximum at R+100 (587 mg pot^{-1}), which was significantly superior to the other treatments. But treatments U+100 and R+75 remained at par. Similarly R+50 and U+75 also behaved as same .The removal of Ca at N+100 did not differ with U+50. The removal of Mg by maize fodder straw was more or less same as that Ca uptake. In this case, also significantly more Mg removal was recorded at R+100 (453 mg pot^{-1}) but this treatment was statistically at par with U+100. The treatment R+75 and U+75 did not differ between themselves. Similarly the uptake of Mg was also not statistically different from the treatments of NW+100, R+50 and U+50.

The S uptake varied from 21 mg pot^{-1} at NW+0 to 297 mg pot^{-1} at U+100. The latter treatment was significantly superior to other treatments. At the same level of fertilizer (100 % RDF) the S uptake at NW+100 was significantly lower than that at U+100 and R+100. The S uptake at NW+100, U+50 and R+50 were statistically same among each other and significantly higher than that of NW+0, U+0 and R+0.

4.1.2.2.3 **Micronutrients**

The results pertaining to concentration of Fe, Mn, Zn and Cu content in maize fodder are presented in table 20. The data presented in table indicated that the maximum concentration of Fe was recorded under the treatments of R+50 (292.5 mg kg^{-1}) followed by R+75 (281.0 mg kg^{-1}). Though the treatments

Table 20. Cumulative effect of diluted effluents and graded fertilizer levels on micronutrient content and their uptake by maize fodder

Treatments	Content (mg kg^{-1})				Uptake (mg pot^{-1})			
Effluent +RDF (%)	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
NW+100	157.5	25.2	19.0	6.7	12.5	2.15	1.62	0.57
R+0	175.5	28.0	17.3	6.3	11.2	1.80	1.10	0.40
R+50	292.5	51.2	26.1	7.6	28.03	4.87	2.48	0.74
R+75	281.0	48.4	25.7	7.7	29.30	5.05	2.69	0.80
R+100	279.5	49.4	26.2	8.2	31.81	5.61	2.98	0.93
U+0	155.0	27.3	15.1	6.3	9.59	1.68	0.82	0.39
U+50	205.0	39.5	24.2	7.4	17.95	3.48	1.30	0.65
U+75	207.5	40.2	23.6	7.4	18.97	3.61	2.16	0.72
U+100	212.5	39.7	23.1	7.4	22.63	4.23	2.48	0.80
NW+0	21.5	14.1	12.3	4.3	0.46	0.30	0.26	0.09
S.Em ±	11.26	1.28	0.88	0.39	1.63	0.19	0.10	0.06
CD at 5%	32.5	3.7	2.6	1.1	4.71	0.54	0.30	0.16

R+100, R+75 and R+50 were at par to each other but significantly superior to treatments of R+0 and NW+100 (157.5 mg pot^{-1}). The Fe concentration recorded under the treatments of U+100, U+75 and U+50 were 212.5, 207.5 and 205.0 mg kg^{-1}, respectively and they were at par to each other but statistically superior to NW+100 and U+0. Almost, similar trend of Mn was noted. The maximum Mn was recorded at R+100 (49.4 mg kg^{-1}) followed by R+75 (48.4 mg kg^{-1}) whereas, the minimum was registered in case of NW+0 (14.1 mg kg^{-1}). In case of Zn content it varied from 12.3 mg kg^{-1} at NW+0 to 26.2 mg kg^{-1} at R+100 treatments. Though the latter treatment was at par with R+75 (25.7 mg kg^{-1}) and R+50 (26.1 mg kg^{-1}) while the former treatment was significantly lower than that of R+0 (17.3 mg kg^{-1}) and U+0 (15.1 mg kg^{-1}). The maximum Cu concentration was recorded in the treatment of R+100 (8.2 mg kg^{-1}). However, this treatment was statistically at par with the treatment effect of R+75 (7.7 mg kg^{-1}), R+50 (7.6 mg kg^{-1}), U+100 (7.4 mg kg^{-1}), U+75 (7.4 mg kg^{-1}) and U+50 (7.4 mg kg^{-1}). The Cu concentration at R+0 (6.3 mg kg^{-1}) and U+0 (6.3 mg kg^{-1}) was at par between themselves but significantly superior to NW+0 (4.3 mg kg^{-1}).

The uptake pattern of Fe, Mn, Zn and Cu was spectacular (Table 20). The uptake of Fe and Mn under the treatment of R+100 was 31.81 and 5.61 mg pot^{-1} followed by R+75 (29.30 and 5.05 mg pot^{-1}). While the uptake of Fe and Mn at the treatment of U+100 were 22.63 and 4.23 mg pot^{-1}. In both the effluents water treatment the uptake of Fe and Mn at R+50 (28.03 and 4.87 mg pot^{-1}) and U+50 (17.95 and 3.48 mg pot^{-1}) were significantly higher as compared to NW+100 (12.50 and 2.15 mg kg^{-1}). From the point of view of Zn, it was maximum at the treatment of R+100 (2.98 mg pot^{-1}), which was statistically at par with treatments of R+75 (2.69 mg pot^{-1}). It is also seen that Zn nutrient removal at R+50 (2.48 mg pot^{-1}) was same as that removed at U+100 (2.48 mg pot^{-1}). These both values were also statistically more as compared to NW+100 (1.62 mg pot^{-1}). With respect to Cu uptake it was varied from 0.09 at NW+0 to 0.93 mg pot^{-1} at R+100 treatment. The latter treatment was statistically better than that of NW+100 (0.57 mg pot^{-1}). Application of 100 per cent RDF and irrigation with UPL effluents removed more Cu as compared to NW+100 (Normal water plus 100 per cent RDF). It is also seen that Cu uptake at R+0 and U+0 was also same as that recorded with NW+100 treatments.

4.1.2.2.4 Heavy metals content

The data regarding the concentration of Ni, Pb, Cd and Co are reported in table 21. The data revealed that concentration of Ni, Pb, Cd and Co differed significantly only with the treatment of NW+0 (0.445, 0.590, ND and 0.735 mg kg^{-1} Ni, Pb, Cd and Co, respectively) the rest of the treatments did not differ statistically among each other.

4.1.2.3 Soil Study

4.1.2.3.1 Physico-chemical properties

Soil reaction, electrical conductivity and organic carbon content of the soil were affected significantly due to different quality of irrigation water (Table 22).

The maximum soil reaction value (8.15 pH) was recorded when the crop was irrigated with normal water without fertilizer followed by N+100 (8.08 pH). Both the values were statistically at par and significantly higher than that of other treatments. The minimum soil reaction value was recorded at 100 % recommended dose of fertilizer with RIL effluents (7.63 pH) followed by R+75(7.67 pH). The pH recorded under UPL effluents irrigation with different levels of fertilizer (0, 50, 75 and 100 % RDF) were non-significant among themselves.

The electrical conductivity (EC) value increased numerically with increase in the fertilizer levels. But the value between R+0 (1.51 dSm^{-1}) and

Table 21. Cumulative effect of diluted effluents and graded fertilizer levels on some heavy metal content in maize fodder

Treatments Effluent+RDF (%)	Heavy metal concentration (mg kg^{-1})			
	Ni	Pb	Cd	Co
NW+100	1.075	1.150	0.040	1.355
R+0	1.103	1.140	0.045	1.370
R+50	1.130	1.150	0.042	1.420
R+75	1.122	1.160	0.045	1.395
R+100	1.130	1.155	0.045	1.390
U+0	1.108	1.150	0.040	1.390
U+50	1.115	1.160	0.044	1.420
U+75	1.113	1.145	0.044	1.415
U+100	1.113	1.160	0.044	1.425
NW+0	0.445	0.590	ND	0.735
S.Em ±	0.023	0.029	0.002	0.037
CD at 5%	0.065	0.085	0.006	0.107

Table 22. Cumulative effect of diluted industrial effluents and graded fertilizer levels on physico-chemical properties and major available nutrient status of the soil

Treatments	Physico-chemical properties of soil			Available nutrient status		
Effluent+RDF (%)	pH (1:2.5)	EC (dSm^{-1})	Organic carbon (%)	N	P (ppm)	K
NW+100	8.08	0.78	0.69	149	6.56	265
R+0	7.75	1.51	1.06	438	9.52	250
R+50	7.73	1.60	1.10	445	12.19	260
R+75	7.67	1.69	1.08	459	13.01	275
R+100	7.63	1.65	1.02	470	14.05	291
U+0	7.96	2.47	1.06	185	7.10	280
U+50	7.95	2.50	1.07	194	7.73	310
U+75	7.90	2.59	1.00	191	8.20	330
U+100	7.91	2.65	1.08	196	9.76	347
NW+0	8.15	0.32	0.64	90	4.17	206
S.Em.±	0.04	0.05	0.03	9	0.46	9
C.D at 5%	0.12	0.15	0.08	26	1.33	25

R+50 (1.60 dSm^{-1}) were at par. Similarly EC value between U+0 and U+50 behaved statistically same. The maximum EC value was recorded at U+100 followed by U+75. With the same level of fertilizer dose (100 % recommended dose) the EC value at U+100 (2.65 dSm^{-1}) and R+100 (1.65 dSm^{-1}) was significantly higher as compared to NW+100 (0.78 dSm^{-1}).

Though there were significant differences in the mean organic carbon values due to different effluents water application yet the trend was erratic (Table 22). Further, the organic carbon values due to the different levels of fertilizer treatments varied narrowly from 1.02 % in R+100 to 1.10 % in R+75 in case of RIL effluents water treatments. The corresponding values for UPL effluents ranged from 1.00 % in U+75 to 1.08 % in U+100. Although the 100 % fertilizers treatment with normal water recorded significantly lesser organic carbon status (0.69 %) of the soil than that any of the treatment of effluents water irrigation.

4.1.2.3.2 **Available major nutrients**

The soil available N was significantly affected due to different qualities of irrigation water. The mean available N varied from 90 ppm with NW+O to 470 ppm with R+100 (Table 22). In RIL effluents irrigation, the available N at R+O was significantly lower than that of higher level of fertilizer whereas, in case of UPL effluents irrigation there were non-significant differences due to different levels of fertilizers. Although the value at NW+100 was significantly lower than that of any levels of fertilizers with both the effluent irrigation. Further the N availability was more with RIL effluents irrigation as compared to UPL effluents irrigation.

The available P also statistically differed due to different qualities of irrigation water and levels of fertilizer. It was maximum (14.05 ppm) at R+100, which got reduced (4.17 ppm) at NW+0. There was no significant difference in the effect of R+100 and R+75. But U+100 and U+75 statistically differed. The available P at NW+100 (6.56 ppm) was significantly lower than that of R+O (9.52 ppm) and found same with the treatment effect of U+50.

The available K in the soil was maximum (347 ppm) at U+100, which did not differ significantly from the values at U+75 (330 ppm) but was higher than that of NW+100 (265 ppm). Though the value at R+50 and NW+100 was the same, but significantly lower than that of values at R+100.

4.1.2.3.3 **DTPA extractable micronutrients**

The maximum Fe content (23.65 mg kg^{-1}) in soil after harvest of maize was observed at the recommended dose of fertilizer and irrigating with RIL effluents water (Table 23). But the value recorded at R+75 and R+50 was at par. Though the lower content (19.66 mg kg^{-1}) was found at R+O, it was significantly higher than that of NW+100. The Fe content varied from 13.24 mg kg^{-1} to 15.76 mg kg^{-1}in UPL effluents irrigation treatments. But these both value were significantly better than that of NW+100 (10.71 mg kg^{-1})

Similar to Fe content, the maximum content of Mn was recorded at R+100 followed by R+75, which were significantly higher than that of NW+100 treatment. The values recorded in 100 %, 75 % and 50 % fertilizer dose alongwith UPL effluents irrigation were statistically at par with each other and significantly superior to NW+100. Further, Mn content at, U+O and R+O was also more as compared to NW+100 and NW+O.

The Zn content increased from 0.95 mg kg^{-1} at NW+100 to 1.20 mg kg^{-1} at U+100 and 1.28 mg kg^{-1} at 100 % RDF alongwith RIL effluents irrigation. The values recorded at R+50, R+75, and R+100 statistically remained same but significantly superior to NW+100. Similarly the values of 1.20 mg kg^{-1} and 1.19 mg kg^{-1} recorded at U+100 and U+75, respectively were also same but statically better than that of NW+100 (0.95 mg kg^{-1}).

Table 23. Cumulative effect of diluted industrial effluents and graded fertilizer levels on DTPA extractable micro nutrient in soil

Treatments Effluent+ RDF (%)	DTPA- extractable micro nutrients (mg kg^{-1}) Fe	Mn	Zn	Cu
NW+100	10.71	22.50	0.95	3.45
R+0	19.66	35.89	1.03	4.19
R+50	21.43	37.51	1.26	4.18
R+75	21.67	40.80	1.22	4.18
R+100	23.65	44.12	1.28	4.44
U+0	15.30	28.87	1.07	4.22
U+50	13.24	33.38	1.08	3.67
U+75	14.06	32.01	1.19	3.96
U+100	15.76	32.01	1.20	3.86
NW+0	7.74	14.52	0.91	3.15
S.Em±	0.85	1.29	0.05	0.14
C.D at 5%	2.45	3.73	0.15	0.40

The Cu content varied from 3.15 mg kg^{-1} at NW+O to 4.44 mg kg^{-1} at R+100. But the latter value was significantly superior to any other treatments. On an average basis both the effluent irrigation increased the Cu content values as compared to normal irrigation.

4.1.2.3.4 DTPA extractable heavy metals

The soil Ni values of 0.81 mg kg^{-1} at normal water irrigation along with 100 % RDF (NW+100) increased to 0.93 mg kg^{-1} at U+100 and 0.95 mg kg^{-1} at R+100. Further the values of 0.77 mg kg^{-1} at normal water irrigation (NW+O) increased to 0.88 mg kg^{-1} at U+O and 0.90 mg kg^{-1} at R+0 treatments (Table 24).

As against the Ni content, the Cd content was found to be non-significant. While concentration of Pb in the soil was increased from 1.13 mg kg^{-1} at NW+100 to 1.28 mg kg^{-1} at U+100 and 1.33 mg kg^{-1} at R+100. In both the effluents due to different levels of fertilizer, there was no significant difference of Pb observed.

The Co content in soil was found to be significant due to different treatments. Based on the mean value of different treatments it is observed that application of both effluent water increased the values of DTPA extractable Co content in soil as compared to normal water irrigation. The maximum was recorded at U+75 (1.08 mg kg^{-1}) and the minimum was observed at NW+O (0.66 mg kg^{-1}).

4.2 Feasibility of fertilizer reduction through solid wastes

To explore the feasibility of saving the fertilizer with the usage of solid waste, field experiments were conducted at soil and water management, farm. The different solid waste such as biological sludge, pressmud and biocompost were applied @ 5 t ha^{-1} with full and half recommended doses to study their

Table 24. Cumulative effect of diluted effluents and graded fertilizer levels on DTPA extractable heavy metal status of the soil

Treatments	Heavy metal concentration (mg kg-1)			
Effluent +RDF (%)	Ni	Cd	Pb	Co
NW+100	0.81	0.068	1.13	0.75
R+0	0.90	0.078	1.28	0.76
R+50	0.93	0.070	1.32	0.73
R+75	0.95	0.080	1.30	0.83
R+100	0.95	0.075	1.33	0.95
U+0	0.88	0.080	1.19	0.90
U+50	0.91	0.083	1.29	0.93
U+75	0.92	0.085	1.28	1.08
U+100	0.93	0.080	1.28	1.00
NW+0	0.77	0.060	1.06	0.66
S.Em ±	0.02	0.005	0.05	0.02
CD at 5%	0.05	NS	0.13	0.06

direct effect on cabbage crop and residual effect on summer groundnut. The results are presented below.

4.2.1 Direct effect on cabbage crop

4.2.1.1 Fresh and dry matter yield

Data pertaining to the fresh and dry matter yield of Cabbage head and stump (unwrapped leaves + stem) as affected by the various treatments are presented in table 25.

The results indicated significant differences in fresh and dry matter yield of cabbage head, due to application of different solid wastes alongwith 100 and 50 per cent recommended fertilizer doses. Significantly highest fresh and dry matter head yield (25.91 t ha^{-1} and 3050 kg ha^{-1}) were obtained in case of biological sludge applied @ 5 t ha^{-1} with 100 per cent recommended dose of fertilizer (T_3). However, yield produced at this treatment was statistically at par with the treatment effect of T_4 (FYM @ 5 t ha^{-1} + 100 per cent RDF), T_5 (pressmud @ 5 t ha^{-1}+100 % RDF and T_6 (Biocompost @ 5 t ha^{-1}+100 % RDF) which yielded 24.65, 23.00 and 23.07 t ha^{-1} fresh and 2909, 2699 and 2723 kg ha^{-1} dry matter heads, respectively. Further, yield produced under treatments of T_3, T_4, T_5 and T_6 were significantly superior to control (100 per cent RDF only). It is also interesting to note that the yield (Fresh and dry) obtained with half recommended dose alongwith application of BS (biological sludge), PM (pressmud), FYM and BC (biocompost) were statistically at par with control (T_1). The application of BS (T_3), FYM (T_4), PM (T_5), and BC (T_6) alongwith full recommended dose yielded 34.89, 28.60, 19.37 and 20.43 per cent higher dry matter head yield, respectively over control.

Cabbage stump yield (unwrapped leaves + stem) was also significantly higher with application of solid waste in conjunction with 100 per cent RDF. At the same level of fertilizer (100 per cent recommended dose), the dry stump

Table 25. Direct effect of different industrial solid wastes with graded fertilizer levels on cabbage head diameter, fresh and dry yield of cabbage head and stump

Treatments	Cabbage head			Stump	
	Head diameter (cm)	Fresh yield (t ha^{-1})	Dry yield (kg ha^{-1})	Fresh yield (t ha^{-1})	Dry yield (kg ha^{-1})
T_1= Control-100 % RDF	11.51	19.17	2261	17.91	2687
T_2=BS 2.5t/ha +100%RDF	12.14	21.57	2545	19.42	2838
T_3=BS 5t/ha +100%RDF	14.19	25.91	3050	24.09	3614
T_4=FYM 5t/ha +100%RDF	13.85	24.65	2909	20.55	3307
T_5=PM 5t/ha +100%RDF	13.75	23.00	2699	20.66	3100
T_6= BC 5t/ha +100%RDF	13.75	23.07	2723	20.95	3144
T_7=BS 2.5t/ha +50%RDF	11.88	17.98	2121	17.25	2589
T_8=BS 5t/ha +50%RDF	12.35	22.53	2659	21.65	3248
T_9=FYM 5t/ha +50%RDF	11.93	19.94	2357	17.50	2623
T_{10}=PM 5t/ha +50%RDF	11.46	17.24	2035	16.75	2512
T_{11}=BC 5t/ha +50%RDF	11.88	18.85	2342	17.63	2645
S.Em ±	0.29	1.29	152	1.27	172
CD at 5%	0.84	3.73	437	3.65	497

yield produced at T_3 (3614 kg ha^{-1}) T_4 (3307 kg ha^{-1}) and T_6 (3144 kg ha^{-1}) were at par with each other and significantly higher to control (2687 kg ha^{-1}). Moreover, the stump yield at control was statistically lower than that of T_8 (50 per cent RDF+ biological sludge @ 5 t ha^{-1}). Though there were practically no differences in stump yield produced at T_1, T_7, T_9, T_{10} and T_{11} treatments.

Head diameter pattern as affected by different treatments was almost similar to head yield. The maximum head diameter (14.19 cm) was noted at T_3 treatment followed by T_4 (13.85 cm), T_5 (13.75 cm) and T_6 (13.75 cm). All these were behaved as like and significantly higher as compared to control (11.51 cm). Moreover, application of different solid waste alongwith 50 per cent RDF (T_8, T_{10} and T_{11} treatments) recorded statistically same head diameter as that obtained in control.

4.2.1.2 Nutrient content and uptake

4.2.1.2.1 Major nutrients

The data presented in the table 26 revealed that major nutrient contents and their uptake by cabbage head were significantly influenced due to application of solid waste with full and half doses of fertilizer.

Though the N content varied narrowly from 2.64 per cent to 2.79 per cent yet the significant difference was observed among the treatments. The maximum N content was recorded at application of biological sludge @ 5 t ha^{-1} plus 100 per cent RDF (T_3). It was significantly superior to rest of the treatments. Besides, treatments T_4, T_5, T_6 and T_8 were statistically at par. Similarly, the treatments T_1, T_7, T_9, T_{10} and T_{11} were also at par.

The P content also varied narrowly from 0.83 per cent at T_7 to 0.94 per cent at T_3 treatment, both of them significantly differed. Though the former treatment (T_7) statistically differed from that of any treatments except control. The K content was maximum (2.42 %) in biocompost with full recommended

Table 26. Direct effect of different industrial solid wastes with graded fertilizer levels on content and uptake of major nutrient by cabbage head

Treatments	Content (%)			Uptake (kg ha^{-1})		
	N	P	K	N	P	K
T_1=Control- 100 % RDF	2.66	0.86	2.30	60.11	19.45	51.98
T_2=BS 2.5t/ha +100%RDF	2.67	0.88	2.30	67.87	22.38	58.49
T_3=BS 5t/ha +100%RDF	2.79	0.94	2.32	85.05	28.44	70.58
T_4=FYM 5t/ha +100%RDF	2.68	0.93	2.36	77.90	27.11	65.55
T_5=PM 5t/ha +100%RDF	2.70	0.92	2.39	72.72	24.72	64.40
T_6=BC 5t/ha +100%RDF	2.72	0.94	2.42	73.85	25.53	65.82
T_7=BS 2.5t/ha +50%RDF	2.68	0.83	2.28	56.77	19.06	50.02
T_8=BS 5t/ha +50%RDF	2.74	0.89	2.30	72.96	23.61	61.09
T_9=FYM 5t/ha +50%RDF	2.64	0.88	2.33	62.83	20.82	55.30
T_{10}=PM 5t/ha +50%RDF	2.64	0.88	2.34	53.84	17.76	47.53
T_{11}=BC 5t/ha +50%RDF	2.64	0.90	2.36	61.88	19.37	53.24
S.Em ±	0.02	0.02	0.02	4.14	1.07	3.05
CD at 5%	0.05	0.06	0.06	11.97	3.09	8.82

dose of fertilizer treatment (T_6). But it was at par with either pressmud (T_5) or FYM (T_4) alongwith 100 per cent RDF. The content recorded at 100 per cent RDF only (control) was at par with T_2, T_3, T_4, T_7, T_8, T_9, T_{10} and T_{11} treatments.

The N uptake by cabbage head at full dose of inorganic fertilizer alone was 60.11 kg ha^{-1}, which was statistically at par with that obtained in 50 per cent fertilizer dose with application of either 2.5 t ha^{-1} biosludge (56.77 kg ha^{-1}) or 5 t ha^{-1} FYM (62.83 kg ha^{-1}) or 5 t ha^{-1} pressmud (53.84 kg ha^{-1}) or 5 t ha^{-1} biocompost (61.88 kg ha^{-1}). But these removals of N were significantly lower than that recorded with T_3 (85.05 kg ha^{-1}), T_5 (72.72 kg ha^{-1}), T_6 (73.85 kg ha^{-1} and T_8 (72.96 kg ha^{-1}).

The maximum P (28.44 kg P ha^{-1}) was removed at the 100 per cent recommended dose of fertilizer with application of biosludge @ 5 t ha^{-1} (T_3) which was at par with T_4 and T_6. The latter two treatments were also at par with T_5. Though the lowest uptake was found at T_{10} (17.76 kg ha^{-1}) but it was at par with the treatment effect of T_1, T_7, T_9 and T_{11}.

The K uptake was also maximum (70.58 kg ha^{-1}) at T_3 followed by T_4, T_6 and T_5, these treatments were statistically at par with each other. In this case also the removal recorded at T_1, T_7, T_9, T_{10} and T_{11} did not differ significantly. Similarly T_4 and T_8 behaved practically same.

The N content of the stump varied from 2.19 % (T_7) to 2.29 % (T_3 and T_6). Both the values differed significantly (Table 27). With the same level of fertilizer dose (100 % recommended dose), the N content at T_3 (2.29 %), T_4 (2.26 %), T_5 (2.28 %) and T_6 (2.29 %) were significantly higher as compared to control (2.20 %). There were no significant difference in contents recorded among the treatment of T_1, T_7, T_8, T_9, T_{10} and T_{11}. Pattern of P content by cabbage stump was similar to N contents. The K contents in the stump was maximum (3.50 %) at 100 % RDF with application of @ 5 t ha^{-1} biocompost

Table 27. Direct effect of different industrial solid wastes with graded fertilizer levels on content and uptake of major nutrient by cabbage stump

Treatments	Content (%)			Uptake (kg ha^{-1})		
	N	P	K	N	P	K
T_1=Control-100 % RDF	2.20	0.33	3.38	59.03	8.81	90.47
T_2=BS 2.5t/ha +100%RDF	2.23	0.34	3.39	63.29	9.57	96.05
T_3=BS 5t/ha +100%RDF	2.29	0.39	3.40	82.62	14.03	122.78
T_4=FYM 5t/ha +100%RDF	2.26	0.37	3.45	76.77	12.46	117.03
T_5=PM 5t/ha +100%RDF	2.28	0.40	3.48	70.57	12.37	107.84
T_6=BC 5t/ha +100%RDF	2.29	0.39	3.50	71.75	12.20	109.90
T_7=BS 2.5t/ha +50%RDF	2.19	0.32	3.36	56.63	8.23	86.96
T_8=BS 5t/ha +50%RDF	2.21	0.34	3.36	71.65	10.96	109.00
T_9=FYM 5t/ha +50%RDF	2.20	0.33	3.38	57.68	8.63	88.64
T_{10}=PM 5t/ha +50%RDF	2.20	0.34	3.40	55.35	8.58	85.35
T_{11}=BC 5t/ha +50%RDF	2.21	0.35	3.39	58.50	9.24	89.73
S.Em ±	0.01	0.014	0.03	3.61	0.41	5.42
CD at 5%	0.03	0.04	0.08	10.42	1.18	15.59

(T_6), which did not differ statistically from the value at T_5 (3.48 %) and T_4 (3.45 %), but its were higher than that of T_1 (3.38 %). The values registered among the treatment of T_1, T_7, T_8, T_9, T_{10} and T_{11} were remained practically same.

The N uptake by stump varied from 55.35 kg ha^{-1} at 50 % RDF alongwith application of pressmud @ 5 t ha^{-1} (T_{10}) to 82.62 kg ha^{-1} at T_3. All the solid waste treatments with 100 % RDF resulted in higher N uptake than that of control. But the treatments T_1, T_2, T_7, T_9, T_{10} and T_{11} remained at par with each other. The P uptake was maximum (14.03 kg ha^{-1}) at T_3, it was significantly higher than that of any treatments. But the removal of P at T_4 (12.46 kg ha^{-1}), T_5 (12.37 kg ha^{-1}) and T_6 (12.20 kg ha^{-1}) were also statistically more as compared to control (8.81 kg ha^{-1}). Though the latter treatment (T_1) behaved as like the treatments where solid waste was applied @ 5 t ha^{-1} alongwith 50 % RDF (T_9, T_{10} and T_{11}). The removal of K by the straw was found to be significant. The maximum removal was recorded at T_3 (122.78 kg ha^{-1}) followed by T_4, T_5 and T_6. These four treatments were statistically remained same and significantly superior to control. The K uptake at 50 % RDF with application of either 2.5 t ha biological sludge (T_7) or 5 t ha^{-1} pressmud (T_{10}) or 5 t ha^{-1} biocompost (T_{11}) or 5 t ha^{-1} FYM (T_9) statistically remained same as that obtained at control.

4.2.1.2.2 Secondary Nutrients

The Ca, Mg and S contents were not statistically affected due to the use of different solid waste and fertilizer levels in both the plant parts (Table 28 and 29).

As against the contents, the uptake of all the three nutrients by both the plant parts differed significantly due to different treatments. With regard to Ca uptake by cabbage head it was maximum (40.96 kg ha^{-1}) at T_3 which was significantly superior to other treatments, except T_4. However, treatment (T_4) was statistically at pat with T_5, T_6 and T_8. Similarly the treatment effect of T_1,

Table 28. Direct effect of different industrial solid wastes with graded fertilizer levels on content and uptake of secondary nutrient by cabbage head

Treatments	Content (%)			Uptake (kg ha^{-1})		
	Ca	Mg	S	Ca	Mg	S
T_1=Control-100 % RDF	1.20	0.49	0.59	26.99	11.01	13.20
T_2=BS 2.5t/ha +100%RDF	1.27	0.51	0.62	32.09	12.95	15.61
T_3=BS 5t/ha +100%RDF	1.35	0.54	0.66	40.96	16.36	19.88
T_4=FYM 5t/ha +100%RDF	1.31	0.56	0.65	37.93	16.05	18.61
T_5=PM 5t/ha +100%RDF	1.31	0.53	0.66	35.15	14.30	17.64
T_6=BC 5t/ha +100%RDF	1.32	0.53	0.67	35.79	14.39	18.13
T_7=BS 2.5t/ha +50%RDF	1.28	0.51	0.61	26.96	10.65	12.79
T_8=BS 5t/ha +50%RDF	1.31	0.51	0.63	34.62	13.53	16.55
T_9=FYM 5t/ha +50%RDF	1.27	0.52	0.62	29.94	12.16	14.53
T_{10}=PM 5t/ha +50%RDF	1.30	0.50	0.61	26.43	10.07	12.23
T_{11}=BC 5t/ha +50%RDF	1.30	0.51	0.63	30.53	11.84	14.55
S.Em ±	0.03	0.02	0.03	1.50	0.41	0.63
CD at 5%	NS	NS	NS	4.33	1.18	1.82

Table 29. Direct effect of different industrial solid wastes with graded fertilizer levels on content and uptake of secondary nutrient by cabbage stump

Treatments	Content (%)			Uptake (kg ha^{-1})		
	Ca	Mg	S	Ca	Mg	S
T_1=Control-100 % RDF	1.59	0.81	0.71	42.41	21.58	18.92
T_2=BS 2.5t/ha +100%RDF	1.63	0.84	0.73	46.17	23.63	20.88
T_3=BS 5t/ha +100%RDF	1.66	0.89	0.80	60.48	32.28	28.63
T_4=FYM 5t/ha +100%RDF	1.65	0.86	0.78	55.81	28.80	26.25
T_5=PM 5t/ha +100%RDF	1.64	0.89	0.79	50.88	27.47	24.26
T_6=BC 5t/ha +100%RDF	1.66	0.90	0.80	52.06	28.08	24.72
T_7=BS 2.5t/ha +50%RDF	1.63	0.81	0.73	42.00	20.78	18.73
T_8=BS 5t/ha +50%RDF	1.64	0.85	0.76	53.19	27.34	24.60
T_9=FYM 5t/ha +50%RDF	1.63	0.86	0.75	42.71	22.38	19.56
T_{10}=PM 5t/ha +50%RDF	1.62	0.84	0.74	40.62	21.00	18.42
T_{11}=BC 5t/ha +50%RDF	1.63	0.86	0.74	43.80	22.56	19.46
S.Em ±	0.03	0.03	0.03	2.27	1.24	0.87
CD at 5%	NS	NS	NS	6.55	3.59	2.52

T_7, T_9, T_{10} and T_{11} also remained at par. Almost the more or less similar pattern of removal was also observed in case of Ca uptake by stump and Mg uptake by head as well as stump. The S uptake by both cabbage head and stump differed significantly due to different treatments. In both cases,it was the highest at T_3 (19.87 kg ha^{-1} by head and 28.63 kg ha^{-1} by stump) followed by T_4 treatment. But in case of head uptake, the treatment T_6 also practically remained same with T_3 and T_4 100 % RDF (T_1) remained statistically at par with the treatment of 50 % RDF alongwith solid wastes application in both the cases.

4.2.1.2.3 Micronutrients

The results regarding the concentration of Fe, Mn, Cu and Zn in cabbage head and stump at harvest stage are reported in table 30 and 31, respectively. Concentration of Fe in head varied significantly between 58.83 to 74.41 mg kg^{-1} due to material used. Significantly higher concentration of Fe in head was recorded with application of biosludge @ 5 t ha^{-1} plus 100 per cent RDF (74.41 mg kg^{-1}) which was at par with rest of the treatments barring, control (58.83 mg kg^{-1}) and application of biosludge @ 2.5 t ha^{-1} plus 100 per cent RDF (66.14 mg kg^{-1}). In cabbage stump, the higher and lower content of Fe was registered with BS @ 5 t ha^{-1} plus 100 per cent RDF treatment (60.95 mg kg^{-1}) and control (49.49 mg kg^{-1}), respectively. The stump Fe content registered with half doses of fertilizer alongwith either application of biosludge @ 5 t ha^{-1} (57.42 mg kg^{-1}) or FYM (52.45 mg kg^{-1}) or pressmud (54.55 mg kg^{-1}) or biocompost (55.38 mg kg^{-1}) was significantly higher than that of application of 100 per cent RDF alone (49.49 mg kg^{-1}). The Mn content remained unaffected due to different solid waste materials and fertilizer doses in head and stump (Table 30 and 31). With respect to Zn content, it was noteworthy in head only. Among the different treatments biosludge @ 5 t ha^{-1} in conjunction with 100 per cent RDF recorded comparatively higher value of Zn (23.97 mg kg^{-1}). However, it remained at par

Table 30. Direct effect of different industrial solid wastes with graded fertilizer levels on micronutrient content and their uptake by cabbage head

Treatments	Content (mg kg^{-1})				Uptake (g ha^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T_1=Control- 100 % RDF	58.83	23.73	18.63	6.79	132.96	53.87	42.09	15.40
T_2=BS 2.5t/ha +100%RDF	66.14	26.61	22.75	7.13	168.66	67.68	57.98	18.09
T_3=BS 5t/ha +100%RDF	74.41	27.30	23.97	7.61	226.93	83.57	72.70	23.13
T_4=FYM 5t/ha +100%RDF	69.40	25.15	20.92	7.44	201.75	73.45	61.36	21.65
T_5=PM 5t/ha +100%RDF	69.77	24.85	21.28	6.91	187.90	67.13	57.60	18.69
T_6=BC 5t/ha +100%RDF	72.03	25.33	21.38	6.98	196.48	69.25	58.33	18.89
T_7=BS 2.5t/ha +50%RDF	69.88	23.38	20.24	6.79	148.20	49.67	43.06	14.32
T_8=BS 5t/ha +50%RDF	73.22	25.63	21.63	7.45	195.04	67.86	57.69	19.77
T_9=FYM 5t/ha +50%RDF	70.40	24.23	20.98	7.12	167.26	57.42	50.67	16.40
T_{10}=PM 5t/ha +50%RDF	71.63	25.63	20.86	6.97	146.34	51.83	42.73	14.03
T_{11}=BC 5t/ha +50%RDF	72.85	24.85	21.19	7.21	170.32	58.32	48.76	16.96
S.Em $\pm$	1.59	1.20	1.52	0.43	11.91	5.32	5.54	1.41
CD at 5%	4.59	NS	4.38	NS	34.39	15.36	16.00	4.08

Table 31. Direct effect of different industrial solid wastes with graded fertilizer levels on micronutrient content and their uptake by cabbage stump

Treatments	Content (mg kg^{-1})				Uptake (g ha^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T_1=Control-100 % RDF	49.49	19.53	14.82	4.41	133.86	53.40	39.47	12.39
T_2=BS 2.5t/ha +100%RDF	55.87	20.83	16.38	5.10	159.52	58.74	47.03	14.25
T_3=BS 5t/ha +100%RDF	60.95	22.42	18.61	5.63	222.00	80.63	67.55	20.08
T_4=FYM 5t/ha +100%RDF	54.20	20.17	17.34	4.90	180.50	68.17	58.67	16.27
T_5=PM 5t/ha +100%RDF	56.14	21.67	17.50	4.55	173.68	67.22	49.53	13.62
T_6=BC 5t/ha +100%RDF	56.90	22.32	17.97	5.03	179.50	69.92	56.83	15.53
T_7=BS 2.5t/ha +50%RDF	53.65	19.57	15.54	5.07	137.87	51.20	40.22	13.21
T_8=BS 5t/ha +50%RDF	57.42	20.85	16.60	4.85	186.18	67.29	53.21	15.80
T_9=FYM 5t/ha +50%RDF	52.45	21.28	15.32	4.90	137.34	56.14	40.36	12.91
T_{10}=PM 5t/ha +50%RDF	54.55	21.40	16.98	4.48	137.05	53.80	42.56	11.13
T_{11}=BC 5t/ha +50%RDF	55.38	20.93	16.93	4.68	146.65	55.15	44.84	12.34
S.Em ±	1.58	1.57	0.81	0.44	11.98	5.56	4.37	1.17
CD at 5%	4.56	NS	NS	NS	34.59	16.06	12.63	3.38

with the rest of the treatments, except control (18.63 mg kg^{-1}). Cu content in cabbage head and stump did not exert any indicative influence due to various treatments.

The data regarding the uptake of Fe, Mn, Zn and Cu by head and stump are reported through tables 30 and 31. In head and stump of cabbage, Fe uptake was significantly influenced due to different treatments. Application of biosludge @ 5 t ha^{-1} plus 100 per cent RDF removed importantly highest amount of Fe (226.93 g ha^{-1}) which was at par with FYM plus 100 per cent RDF (201.75 g ha^{-1}), biocompost plus 100 per cent RDF (196.48 g ha^{-1}) and biosludge @ 5 t ha^{-1} plus 50 per cent RDF (195.04 g ha^{-1}).

In contrast, control treatment removed lowest amount of Fe i.e. 132.96 g ha^{-1} and statistically it was at par with BS @ 2.5 t ha^{-1}+50 per cent RDF (148.20 g ha^{-1}), FYM+50 per cent RDF (167.26 g ha^{-1}), pressmud + 50 per cent RDF (146.34 g ha^{-1}) and biocompost plus 50 percent RDF (170.32 g ha^{-1}). In case of stump, application of BS @ 5 t ha^{-1} in conjunction with 100 per cent RDF (222.00 g ha^{-1}) ranked first and next in order were BS plus 50 per cent RDF (186.18 g ha^{-1}), BC plus 100 per cent RDF (179.50 g ha^{-1}) and PM plus 100 per cent RDF (173.68 g ha^{-1}). Considerably lower Fe uptake value of 133.86 g ha^{-1} was obtained with control but it was at par with, FYM, BC and PM along with 50 per cent RDF (T_9, T_{10} and T_{11} treatments). Similarly, BS @ 2.5 t ha^{-1} alongwith half and full doses of in- organic fertilizer were also remained at par with control.

Like Fe, Mn uptake also differed remarkably due to different treatment effect. In case of head, application of BS @ 2.5t ha^{-1} alongwith 50 per cent RDF (49.67 g ha^{-1}) registered significantly less value of Mn uptake but it was at par with application of 50 per cent RDF in conjunction with either FYM (57.42 g ha^{-1}) or PM (51.83 g ha^{-1}) or BC (58.32 g ha^{-1}) and control (53.67 g ha^{-1}). Where..

as, application of 100 per cent RDF in concomitant with BS @ 5t ha^{-1} (83.57 g ha^{-1}), FYM (73.45 g ha^{-1}), PM (67.13 g ha^{-1}) and biocompost (69.25 g ha^{-1}) established its' superiority by removing the more Mn as compared to control. With respect to Mn uptake by stump application of biosludge @ 5 t ha^{-1} plus 100 per cent RDF (80.63 g ha^{-1}) noted significantly higher Mn uptake in comparison to rest of the treatments. However, it was at par with application of 100 per cent RDF along with either FYM (68.17 g ha^{-1}) PM (67.22 g ha^{-1}) and BC (69.92 g ha^{-1}). Application of BS @5 t ha^{-1} plus 50 per cent RDF (67. 29 g ha^{-1}) was also at par with these treatments. Significantly lower value was recorded with application of BS @ 2.5t ha^{-1} along with 50 per cent RDF (51.20 g ha^{-1}) and it was at par with remaining treatments.

From Zn uptake point of view in head, application of 100 per cent recommended inorganic fertilizer along with BS @ 5 t ha^{-1} (72.70 g ha^{-1}), FYM (61.36 g ha^{-1}), PM (57.60 g ha^{-1}) and BC (58.33 g ha^{-1}) showed superiority over rest of the treatments except, T_8 treatment (BS @ 5t ha^{-1}plus 50 per cent RDF). In rest of the treatments uptake of Zn by head varying between 42.09 to 50.67 g ha^{-1} except, T_2 treatments which removed 57.98 g ha^{-1} Zn. Zn uptake by stump was significantly higher with application of BS @ 5 t ha^{-1} in conjunction with 100 per cent RDF (67.55 g ha^{-1}) which was statistically at par with BC plus 100 per cent RDF (56.83 g ha^{-1}) and FYM plus 100 per cent RDF (58.67 g ha^{-1}). The removal of Zn by stump was minimum with control (39.47 g ha^{-1}) and which were at par with remaining treatments except T_8 (53.21 g ha^{-1}). In rest of the treatments Zn uptake was around 40 to 47 g ha^{-1}.

In case of Cu uptake by head, the maximum (23.13 g ha^{-1}) was recorded with application of BS @ 5 t ha^{-1}alongwith 100 per cent RDF followed by FYM plus 100 per cent RDF (21.65 g ha^{-1}). Significantly lower Cu uptake was recorded with application of PM @ 5 t ha^{-1} along with 50 per cent RDF (14.03 g

ha^{-1}) and it was at par with remaining treatments except T_8, which removed 19.77 g ha^{-1} Cu. The uptake pattern of Cu by cabbage stump was almost similar to that of Cu uptake by head, in most of the treatments. The uptake value varied from 11.13 to 20.08 g ha^{-1}.

4.2.1.2.4 Heavy metal content

Data given in table 32 indicated that different treatment did not exert any significant influence on Ni, Pb, Cd and Co content of cabbage head and stump.

The concentration of Ni, Pb, Cd and Co varied from 0.928 to 0.937, 0.840 to 0.847, 0.019 to 0.023 and 0.760 to 0.769 mg kg^{-1} in head respectively. While the corresponding values of respective metal in cabbage stump fluctuated from 1.179 to 1.200, 0.975 to 0.980, 0,031 to 0.034 and 0.880 to 0.889 mg kg^{-1}

4.2.1.3 Soil changes

4.2.1.3.1 Physico-chemical properties

The different levels of fertilizer and application of different solid waste did not influence the soil reaction value (Table 33). It varied from 8.07 (T_7) to 8.22 (control).

The electrical conductivity (EC) values increased only where the biological sludge was applied (T_2, T_3, T_7 and T_8) treatments as compared to control. Whereas, pressmud and biocompost failed for such effect.

Organic carbon status of the soil increased numerically when the solid waste was applied but was failed to reach the significant level. It varied from 0.39 % at control to 0.52 % at T_3 treatments. The organic carbon status at T_4, T_5 and T_6 was 0.49 %, 0.47 % and 0.51 %, respectively.

4.2.1.3.2 Available major nutrients

The maximum available N (251 kg ha^{-1}) was recorded at 100% RDF with application of 5 t ha^{-1} biological sludge (Table 34). Though this treatment statistically remained same with T_2, T_4, T_5 and T_6 yet significantly superior to control. The available N recorded at T_7, T_8, T_9, T_{10} and T_{11} was 211, 214, 208,

Table 32. Direct effect of different industrial solid wastes with graded fertilizer levels on heavy metal content in cabbage crop

Treatments	Head (mg kg^{-1})				Stump (mg kg^{-1})			
	Ni	Pb	Cd	Co	Ni	Pb	Cd	Co
T_1=Control-100 % RDF	0.928	0.840	0.019	0.760	1.179	0.975	0.031	0.880
T_2=BS 2.5t/ha +100%RDF	0.933	0.841	0.021	0.764	1.188	0.979	0.032	0.883
T_3=BS 5t/ha +100%RDF	0.937	0.847	0.022	0.767	1.200	0.980	0.034	0.889
T_4=FYM 5t/ha +100%RDF	0.931	0.846	0.022	0.767	1.118	0.976	0.032	0.882
T_5=PM 5t/ha +100%RDF	0.933	0.846	0.022	0.769	1.191	0.977	0.034	0.884
T_6=BC 5t/ha +100%RDF	0.934	0.845	0.023	0.766	1.194	0.979	0.034	0.885
T_7=BS 2.5t/ha +50%RDF	0.935	0.844	0.021	0.763	1.190	0.977	0.032	0.881
T_8=BS 5t/ha +50%RDF	0.934	0.845	0.022	0.767	1.194	0.970	0.033	0.884
T_9=FYM 5t/ha +50%RDF	0.932	0.884	0.022	0.766	1.193	0.978	0.033	0.884
T_{10}=PM 5t/ha +50%RDF	0.935	0.845	0.022	0.764	1.192	0.979	0.031	0.887
T_{11}=BC 5t/ha +50%RDF	0.935	0.845	0.022	0.764	1.192	0.979	0.033	0.884
S.Em $\pm$	0.004	0.002	0.002	0.003	0.004	0.002	0.002	0.002
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Table 33. Direct effect of different industrial solid wastes and graded fertilizer levels on physico-chemical characteristics of the soil

Treatments	Physicochemical characteristics		
	pH (1:2.5)	EC (dSm^{-1})	Organic carbon (%)
T_1=Control-100 % RDF	8.22	0.17	0.39
T_2=BS 2.5t/ha +100%RDF	8.11	0.33	0.45
T_3=BS 5t/ha +100%RDF	8.08	0.35	0.52
T_4=FYM 5t/ha +100%RDF	8.23	0.21	0.49
T_5=PM 5t/ha +100%RDF	8.18	0.19	0.47
T_6=BC 5t/ha +100%RDF	8.22	0.19	0.51
T_7=BS 2.5t/ha +50%RDF	8.11	0.26	0.44
T_8=BS 5t/ha +50%RDF	8.07	0.28	0.51
T_9=FYM 5t/ha +50%RDF	8.19	0.19	0.47
T_{10}=PM 5t/ha +50%RDF	8.18	0.18	0.48
T_{11}=BC 5t/ha +50%RDF	8.16	0.20	0.46
S.Em ±	0.04	0.02	0.03
CD at 5%	NS	0.05	NS

Table 34. Direct effect of different industrial solid wastes and graded fertilizer levels of on available major nutrient status of the soil

Treatments	Available nutrients (kg ha^{-1}) Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
T_1=Control-100 % RDF	196	30.65	581
T_2=BS 2.5t/ha +100%RDF	231	37.27	622
T_3=BS 5t/ha +100%RDF	251	46.03	644
T_4=FYM 5t/ha +100%RDF	235	41.31	658
T_5 PM 5t/ha +100%RDF	233	41.33	710
T_6=BC 5t/ha +100%RDF	227	45.94	726
T_7=BS 2.5t/ha +50%RDF	211	30.30	599
T_8=BS 5t/ha +50%RDF	214	35.37	610
T_9=FYM 5t/ha +50%RDF	208	32.61	622
T_{10}=PM 5t/ha +50%RDF	211	31.03	646
T_{11}=BC 5t/ha +50%RDF	198	31.64	640
S.Em $\pm$	8.00	1.53	16
CD at 5%	24.00	4.42	46

211 and 198 kg ha^{-1}, respectively which were at par with each other and practically remained same with control.

The available P_2O_5 varied from 30.30 kg ha^{-1} at application of 50 % RDF with 2.5 t ha^{-1} biological sludge (T_7) to 46.03 kg ha^{-1} at T_3. Both of them significantly did differ between themselves. The latter treatment was significantly superior to rest of the treatment except T_6 (45.94 kg ha^{-1}). The treatment T_1, T_7, T_9, T_{10} and T_{11} were statistically at par with each other. Similarly, T_2 and T_8 also behaved same.

The available K_2O status was maximum (726 kg ha^{-1}) at T_6 treatment followed by T_5. Though at T_4 it was more than T_3, statistically they were at par. These both treatments (T_4 and T_3) were also at par with T_9, T_{10} and T_{11}. Similarly the treatments T_1, T_2, T_7, T_8 and T_9 were also practically remained same.

4.2.1.3.3 **DTPA extractable micronutrients**

The Fe content after harvest of cabbage crop was found to be significant (Table 35). The maximum Fe value (13.44 mg kg^{-1}) was recorded at T_6 (application of biocompost + 100 % RDF) followed by T_3 and minimum Fe content (9.39 mg kg^{-1}) was observed at control (100 % RDF). Further 50 % RDF alongwith solid waste material increased the Fe content in soil as compared to control.

As like the Fe, content in soil, the content of Mn was also maximum (22.23 mg kg^{-1}) at T_6, which was at par with T_5 (21.22 mg kg), T_8 (22.03 mg kg^{-1}), T_4 (22.70 mg kg^{-1}), T_3 (20.84 mg kg^{-1}), T_{10} (21.58 mg kg^{-1}) and T_{11} (21.09 mg kg^{-1}). The lowest Mn content was recorded (14.89 mg kg^{-1}) at control and it was significantly lower than that of other treatments.

The Zn content varied considerably due to different treatments. The treatment 100 % RDF (Control) recorded significantly lowest value of Zn

Table 35. Direct effect of different industrial solid wastes and graded fertilizer levels of on micronutrient status of the soil

Treatments	Micro nutrients status (mg kg^{-1})			
	Fe	Mn	Zn	Cu
T_1=Control 100 % RDF	9.39	14.89	0.47	2.25
T_2=BS 2.5t/ha +100%RDF	11.89	18.29	0.80	2.50
T_3=BS 5t/ha +100%RDF	12.86	20.84	0.81	2.87
T_4=FYM 5t/ha +100%RDF	11.59	20.70	0.68	2.38
T_5=PM 5t/ha +100%RDF	12.46	21.22	0.57	2.44
T_6=BC 5t/ha +100%RDF	13.44	22.22	0.58	2.98
T_7=BS 2.5t/ha +50%RDF	11.86	18.01	0.48	2.50
T_8=BS 5t/ha +50%RDF	12.71	22.03	0.69	2.64
T_9=FYM 5t/ha +50%RDF	11.20	19.46	0.61	2.42
T_{10}=PM 5t/ha +50%RDF	11.58	21.58	0.62	2.52
T_{11}=BC 5t/ha +50%RDF	11.53	21.09	0.59	2.43
S.Em ±	0.41	0.82	0.05	0.10
CD at 5%	1.19	2.36	0.14	0.29

content. However, it was at par with T_5 (0.57 mg kg^{-1}), T_6 (0.58 mg kg^{-1}), T_7 (0.48 mg kg^{-1}), T_9 (0.61 mg kg^{-1}) and T_{11} (0.59 mg kg^{-1}). The treatments T_3, T_2, T_8 and T_4 registered significantly higher values of Zn content in decreasing order, though they were at par with one-another.

In case of Cu content in soil after cabbage, it was significantly influenced due to different treatments. Among the different treatments, T_6 (2.98 mg kg^{-1}) recorded comparatively higher value of Cu content followed by T_3 (2.87 mg kg^{-1}). The rest of the treatments statistically same Cu content in the soil.

4.2.1.3.4 DTPA extractable heavy metals

The data reported in table 36 indicated that DTPA extractable Ni, Cd, Pb and Co did not differ significantly due to different treatments.

4.2.2 Residual effect on groundnut crop

4.2.2.1 Dry matter yield

The dry pod yield as affected by residual effect of various solid wastes and fertilizer levels was found to be non significant (Table 37). However, the yield ranged from 2410 kg ha^{-1} at control to 2986 kg ha^{-1} at application of biological sludge alongwith 100 % RDF (T_3). The application of 100 % RDF and either biological sludge (T_3), FYM (T_4) pressmud (T_5) and biopcompost (T_6) each of 5 t ha^{-1} to main crop, increased the yield of residual groundnut pod by 23.10, 19.05, 20.1 and 17.72 %, respectively, over control. As like the dry pod yield, number of mature pod per plant was also found to be non-significant.

As against the dry pod yield, the haulm yield of groundnut was found to be significant due to various treatments. The maximum haulm yield was produced at application of pressmud 5 t ha^{-1} with 100 % RDF (T_5). Though this treatment was at par with T_3, T_4, T_6, T_2 and T_{10} in decreasing order but they were significantly superior to control. The treatment T_7 and T_{11} were also at par with control, whereas, T_8 and T_9 were significantly superior to control.

Table 36. Direct effect of different industrial solid wastes and graded fertilizer levels on heavy metal content of the soil

Treatments	Heavy metal content (mg kg^{-1})			
	Ni	Cd	Pb	Co
T_1=Control-100 % RDF	0.85	0.078	0.81	0.90
T_2=BS 2.5t/ha +100%RDF	0.83	0.075	0.87	0.92
T_3=BS 5t/ha +100%RDF	0.98	0.083	0.97	0.97
T_4=FYM 5t/ha +100%RDF	0.91	0.083	0.91	0.99
T_5=PM 5t/ha +100%RDF	0.88	0.080	0.89	0.95
T_6=BC 5t/ha +100%RDF	0.89	0.085	0.94	0.99
T_7=BS 2.5t/ha +50%RDF	0.85	0.075	0.86	0.97
T_8=BS 5t/ha +50%RDF	0.97	0.085	0.90	0.97
T_9=FYM 5t/ha +50%RDF	0.88	0.075	0.81	0.96
T_{10}=PM 5t/ha +50%RDF	0.90	0.080	0.86	0.94
T_{11}=BC 5t/ha +50%RDF	0.89	0.085	0.91	0.93
S.Em ±	0.04	0.004	0.04	0.03
CD at 5%	NS	NS	NS	NS

Table 37. Residual effect of different industrial solid wastes on number of mature pod plant^{-1}, dry pod and haulm yield of summer groundnut

Treatments	No. of mature pod plant^{-1}	Dry pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
T_1=Control-100 % RDF	21.67	2410	6670
T_2=BS 2.5t/ha +100%RDF	22.90	2768	8662
T_3=BS 5t/ha +100%RDF	24.07	2986	9265
T_4=FYM 5t/ha +100%RDF	25.73	2869	8990
T_5=PM 5t/ha +100%RDF	24.67	2892	9340
T_6=BC 5t/ha +100%RDF	24.50	2837	8898
T_7=BS 2.5t/ha +50%RDF	23.07	2718	7432
T_8=BS 5t/ha +50%RDF	23.13	2876	8106
T_9=FYM 5t/ha +50%RDF	23.00	2715	8011
T_{10}=PM 5t/ha +50%RDF	22.73	2679	8200
T_{11}=BC 5t/ha +50%RDF	23.27	2587	7568
S.Em ±	1.08	202	396
CD at 5%	NS	NS	1140

4.2.2.2 Nutrient content and uptake

4.2.2.2.1 Major nutrient

An appraisal of data presented in table 38 revealed that the content of N, P and K in groundnut pod was not significantly influenced by different treatments. The N content in pod ranged narrowly from 2.62 % at T_7 to 2.75 % at T_3. While P content in pod ranged 0.44 % at T_9 to 0.52 % at T_3 and T_6, similarly K content varied from 0.54 % at T_7 to 0.63 % at T_6.

Similar to the content, the N uptake was also found to be non-significant due to application of solid waste with full and half doses of fertilizer. The highest uptake of P by pod was noted (15.23 kg P ha^{-1}) with application of biological sludge @ 5 t ha^{-1} with 100 % RDF (T_3) followed by T_5 (14.63 kg P ha^{-1}) and T_6 (14.60 kg P ha^{-1}). The lowest uptake of P by pod was recorded at control (10.85 kg P ha^{-1}) but the latter treatment was at par with T_7, T_9, T_{10} and T_{11}. Similarly the value at T_2 and T_8 did not differ significantly. The maximum K uptake by groundnut pod (18.34 kg ha^{-1}) was recorded at application of biocompost @ 5 t ha^{-1} with 100 % RDF, but this value was at par with T_3, T_4 and T_5 treatments.Though the lowest removal was found at control (13.24 kg ha^{-1}), it was at par with T_7 and T_9. Uptake registered at T_{10}, T_{11} and T_2 also statistically at par.

It is evident from the data (Table 39) that application of different type of solid waste alongwith full and half doses of fertilizer to main crop did not exert any residual significant influence on succeeding groundnut haulm content of N, P and K. In contrast, the uptake of N, P and K by haulm was exerting significance influenced due to different treatment. In case of N, the maximum (118.16 kg ha^{-1}) removal was recorded at T_3 treatments followed by T_5, T_6 and T_4 in decreasing order. All of this treatment was significantly better than that of any other treatment. Though the N removal recorded at T_8, T_9, T_{10} and T_{11} were

Table 38. Residual effect of different industrial solid wastes with graded fertilizer levels on content and uptake of major nutrient by groundnut pod

Treatments	Content (%)			Uptake (kg ha^{-1})		
	N	P	K	N	P	K
T_1=Control-100 % RDF	2.65	0.45	0.55	63.86	10.85	13.24
T_2=BS 2.5t/ha +100%RDF	2.68	0.47	0.56	74.18	12.95	15.41
T_3=BS 5t/ha +100%RDF	2.75	0.52	0.58	81.87	15.23	17.04
T_4=FYM 5t/ha +100%RDF	2.74	0.47	0.60	78.54	13.44	17.15
T_5=PM 5t/ha +100%RDF	2.73	051	0.62	78.86	14.63	17.79
T_6=BC 5t/ha +100%RDF	2.75	0.52	0.63	77.81	14.60	18.34
T_7=BS 2.5t/ha +50%RDF	2.62	0.43	0.54	70.89	11.60	14.40
T_8=BS 5t/ha +50%RDF	2.67	0.47	0.56	76.68	13.41	15.97
T_9=FYM 5t/ha +50%RDF	2.65	0.44	0.57	71.76	11.98	14.06
T_{10}=PM 5t/ha +50%RDF	2.66	0.45	0.58	71.18	12.00	15.48
T_{11}=BC 5t/ha +50%RDF	2.67	0.45	0.60	68.90	11.50	16.00
S.Em ±	0.04	0.02	0.03	4.86	0.61	0.71
CD at 5%	NS	NS	NS	NS	1.77	2.06

Table 39. Residual effect of different industrial solid wastes with graded fertilizer levels on content and uptake of major nutrient by groundnut haulm

Treatments	Content (%)			Uptake (kg ha^{-1})		
	N	P	K	N	P	K
T_1=Control-100 % RDF	1.20	0.08	1.16	79.82	5.30	77.28
T_2=BS 2.5t/ha +100%RDF	1.22	0.08	1.18	105.22	6.81	101.64
T_3=BS 5t/ha +100%RDF	1.28	0.09	1.21	118.16	8.15	111.63
T_4=FYM 5t/ha +100%RDF	1.24	0.08	1.20	109.97	6.96	106.83
T_5=PM 5t/ha +100%RDF	1.25	0.09	1.22	116.51	8.17	112.92
T_6=BC 5t/ha +100%RDF	1.27	0.09	1.23	112.69	7.95	109.21
T_7=BS 2.5t/ha +50%RDF	1.21	0.07	1.17	89.76	5.09	86.66
T_8=BS 5t/ha +50%RDF	1.27	0.08	1.18	102.46	6.41	95.32
T_9=FYM 5t/ha +50%RDF	1.22	0.07	1.19	97.45	5.62	95.10
T_{10}=PM 5t/ha +50%RDF	1.22	0.08	1.20	99.81	6.51	96.95
T_{11}=BC 5t/ha +50%RDF	1.24	0.08	1.20	93.57	6.04	90.48
S.Em $\pm$	0.04	0.01	0.03	4.00	0.58	3.59
CD at 5%	NS	NS	NS	11.52	1.68	10.34

at par with each other yet, significantly superior to control. The uptake of P varied from 5.09 kg ha^{-1} at T_7 to 8.17 kg ha^{-1} at T_5. The latter treatment was at par with the values recorded at T_2, T_4, T_6 and T_3 in increasing order. The uptake recorded at T_8, T_9, T_{10}, T_{11} and T_1 were statistically same.

The removal of K by haulm was very conspicuous, significantly lowest removal was recorded at control (77.28 kg ha^{-1}). The K removal observed at T_5, T_3, T_6 and T_4 were practically remained the same and significantly higher than that of any other treatments. The uptake recorded at T_7, T_8, T_{10} and T_{11} were also statistically at par with each other. Similarly the uptake recorded at T_7 and control was also at par.

4.2.2.2.2 Secondary nutrients

It is evident from the data (Table 40) that different solid wastes and fertilizer levels did not evoke any significant influence on content of Ca, Mg and S of groundnut pod.

The Ca uptake varied from 2.56 kg ha^{-1} at control to 4.11 kg ha^{-1} at T_3 (Biological sludge @ 5 t ha^{-1}+ 100 % RDF) but the values differed significantly. The latter treatment statistically at par with T_4 and T_5. The removal of Ca at T_2, T_7, T_8, T_9, T_{10} and T_{11} also practically differed than that of control. The Mg and S uptake was not affected due to any of the treatments.

Data presented in the table 41 indicated that various application of industrial solid waste and graded fertilizer levels did not exert any significant influence on Ca, Mg and S content of groundnut haulm. However, the Ca content varied from 0.54 % at control to 0.62 % at T_3. The corresponding value for Mg and S content at same treatments were 0.47 and 0.15 to 0.51 and 0.19 per cent, respectively.

The uptake pattern by haulm as affected by different treatments was more or less similar in Ca and Mg. In both cases,the total removal by haulm of these

Table 40. Residual effect of different industrial solid wastes with graded fertilizer levels on content and uptake of secondary nutrient by groundnut pod

Treatments	Content (%)			Uptake (kg ha^{-1})		
	Ca	Mg	S	Ca	Mg	S
T_1=Control-100 % RDF	0.11	0.15	0.22	2.56	3.49	5.12
T_2=BS 2.5t/ha +100%RDF	0.12	0.17	0.23	3.30	4.74	6.40
T_3=BS 5t/ha +100%RDF	0.14	0.19	0.25	4.11	5.63	7.49
T_4=FYM 5t/ha +100%RDF	0.13	0.16	0.24	3.71	4.56	6.86
T_5=PM 5t/ha +100%RDF	0.13	0.17	0.24	3.67	4.97	7.00
T_6=BC 5t/ha +100%RDF	0.13	0.18	0.24	3.59	5.04	6.83
T_7=BS 2.5t/ha +50%RDF	0.12	0.16	0.22	3.18	4.43	6.03
T_8=BS 5t/ha +50%RDF	0.12	0.17	0.23	3.40	4.90	6.62
T_9=FYM 5t/ha +50%RDF	0.12	0.16	0.23	3.22	4.36	6.27
T_{10}=PM 5t/ha +50%RDF	0.11	0.16	0.24	2.93	3.96	6.40
T_{11}=BC 5t/ha +50%RDF	0.13	0.17	0.24	3.29	4.40	6.21
S.Em ±	0.01	0.02	0.01	0.17	0.53	0.64
CD at 5%	NS	NS	NS	0.48	NS	NS

Table 41. Residual effect of different industrial solid wastes with graded fertilizer levels on content and uptake of secondary nutrient by groundnut haulm

Treatments	Content (%)			Uptake (kg ha^{-1})		
	Ca	Mg	S	Ca	Mg	S
T_1=Control-100 % RDF	0.54	0.47	0.15	35.98	31.24	9.90
T_2=BS 2.5t/ha +100%RDF	0.55	0.47	0.16	47.32	40.82	13.83
T_3=BS 5t/ha +100%RDF	0.62	0.51	0.19	57.02	47.06	17.42
T_4=FYM 5t/ha +100%RDF	0.60	0.50	0.17	53.42	44.42	14.75
T_5=PM 5t/ha +100%RDF	0.61	0.49	0.18	56.41	45.68	16.56
T_6=BC 5t/ha +100%RDF	0.61	0.50	0.18	54.15	44.37	15.90
T_7=BS 2.5t/ha +50%RDF	0.54	0.48	0.16	40.02	35.56	11.72
T_8=BS 5t/ha +50%RDF	0.59	0.49	0.17	47.72	39.66	13.60
T_9=FYM 5t/ha +50%RDF	0.58	0.48	0.16	46.38	38.37	12.73
T_{10}=PM 5t/ha +50%RDF	0.58	0.48	0.17	47.44	39.29	13.84
T_{11}=BC 5t/ha +50%RDF	0.59	0.49	0.17	44.57	37.06	12.86
S.Em ±	0.02	0.01	0.01	1.73	1.68	0.63
CD at 5%	NS	NS	NS	4.98	4.85	1.81

two elements were statistically maximum at T_3 (57.02 kg ha^{-1} Ca and 47.05 kg ha^{-1} Mg) but these were at par with T_4, T_5 and T_6 in both the cases. The values were minimum at control. Statistically the same amount of these two nutrients was observed to be removed at T_2, T_8, T_9, T_{10} and T_{11}. But all these treatment were significantly superior to control (35.98 kg ha^{-1} Ca and 31.24 kg ha^{-1} Mg). The S uptake by haulm varied widely ranging from 9.90 kg ha^{-1} at control to 17.42 kg ha^{-1} at T_3. At the same levels of fertilizer (100 % recommended dose) the uptake at T_3, T_5, T_6 and T_4 though in decreasing order, they were significantly higher as compared to control (T_1). The removal at the latter treatment was statistically lower than that of T_8, T_9, T_{10} and T_{11} (50 % RDF with solid wastes).

4.2.2.2.3 Micronutrients

It is evident from the data (Table 42) that varying treatments did not exert any indicative influence on contents of Fe, Mn, Zn and Cu of groundnut pod as well as their uptake by pod. However, the highest uptake of Fe (309.2 g ha^{-1}), Mn (294.1 g ha^{-1}), Zn (72.7 g ha^{-1}) and Cu (40.2 g ha^{-1}) was recorded under the treatment of application of BS @ 5 t ha^{-1} alongwith 100 per cent RDF. Whereas, lowest removal of Fe (241.9 g ha^{-1}), Mn (195.0 g ha^{-1}), Zn (51.2 g ha^{-1}) and Cu (30.7 g ha^{-1}) was noted under treatment of control.

With respect to Fe, Mn, Zn and Cu content in haulm of groundnut barring Cu, it was significantly affected due to different treatments (Table 43). Significantly higher concentration of Fe was recorded with BS @ 5 t ha^{-1} plus 100 per cent RDF treatment (151.4 mg kg^{-1}) which was at par with either application of full dose of fertilizer with BC (151.4 mg kg^{-1}) or application of half dose of fertilizer plus BS @ 5 t ha^{-1} (149.2 mg kg^{-1}) or application of half dose of fertilizer alongwith FYM (147.5 mg kg^{-1}) or pressmud application alongwith half dose of fertilizer (146.1 mg kg^{-1}) or biocompost application in

Table 42. Residual effect of different industrial solid wastes with graded fertilizer levels on micronutrient content and their uptake by groundnut pod

Treatments	Content (mg kg^{-1})				Uptake (g ha^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T_1=Control-100 % RDF	100.4	20.3	21.3	12.8	241.9	195.0	51..2	30.7
T_2=BS 2.5t/ha +100%RDF	102.5	21.1	22.5	13.1	283.8	234.7	62.3	36.0
T_3=BS 5t/ha +100%RDF	103.8	24.3	24.1	13.5	309.2	294.1	72.7	40.2
T_4=FYM 5t/ha +100%RDF	102.0	23.0	22.7	13.5	292.3	263.3	65.0`	38.8
T_5=PM 5t/ha +100%RDF	100.8	22.9	23.4	13.2	291.6	263.6	67.4	38.4
T_6=BC 5t/ha +100%RDF	103.0	23.1	23.5	13.3	292.6	263.6	65.4	37.4
T_7=BS 2.5t/ha +50%RDF	98.8	21.9	23.1	13.5	268.1	236.9	63.7	36.5
T_8=BS 5t/ha +50%RDF	106.7	23.6	23.7	13.6	307.2	271.3	67.4	39.0
T_9=FYM 5t/ha +50%RDF	101.6	21.8	23.1	13.6	276.9	238.0	62.7	37.2
T_{10}=PM 5t/ha +50%RDF	100.8	21.8	23.1	13.4	269.7	235.1	62.1	35.7
T_{11}=BC 5t/ha +50%RDF	100.5	22.4	22.5	14.2	259.4	231.5	63.8	36.9
S.Em ±	2.41	1.17	1.38	0.54	21.2	5.99	6.1	2.9
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Table 43. Residual effect of different industrial solid wastes with graded fertilizer levels on micronutrient content and their uptake by groundnut haulm

Treatments	Content (mg kg^{-1})				Uptake (g ha^{-1})			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T_1=Control-100 % RDF	138.2	25.5	16.3	10.3	921	170.3	108.7	68.7
T_2=BS 2.5t/ha +100%RDF	139.7	27.3	18.0	12.8	1211	236.7	155.5	110.0
T_3=BS 5t/ha +100%RDF	151.4	29.3	20.9	13.6	1401	272.0	193.2	125.1
T_4=FYM 5t/ha +100%RDF	143.2	28.3	19.7	13.0	1284	255.0	179.1	116.1
T_5=PM 5t/ha +100%RDF	144.3	29.0	20.3	13.3	1348	270.8	189.5	123.4
T_6=BC 5t/ha +100%RDF	151.4	29.4	20.2	13.4	1347	261.7	179.0	118.9
T_7=BS 2.5t/ha +50%RDF	139.7	27.7	19.2	11.9	1037	205.5	143.0	87.9
T_8=BS 5t/ha +50%RDF	149.2	28.9	20.2	13.0	1210	233.0	163.1	104.4
T_9=FYM 5t/ha +50%RDF	147.5	28.3	19.9	12.7	1183	226.8	159.8	101.2
T_{10}=PM 5t/ha +50%RDF	146.1	28.4	18.7	12.1	1196	232.1	152.6	98.8
T_{11}=BC 5t/ha +50%RDF	145.5	29.3	20.2	12.9	1102	221.6	152.0	97.0
S.Em ±	2.14	0.69	0.80	0.80	71.0	17.7	11.3	9.4
CD at 5%	6.2	2.0	2.3	NS	204.0	51.0	32.6	27.2

conjunction with 50 per cent RDF (145.5 mg kg^{-1}). Control treatment recorded significantly lower concentration of Fe (138.2 mg kg^{-1}) followed by application of 2.5 t ha^{-1} BS along with 100 per cent RDF (139.7 mg kg^{-1}). As far as the Mn content in haulm, all the treatments remained statistically at par, except control, (25.5 mg kg^{-1}). With respect to Zn content, all the treatments behaved practically same barring, control and T_2 (BC @ 2.5 t ha^{-1} plus 100 per cent RDF) which contained 16.3 and 18.00 mg kg^{-1} Zn, respectively.

Data regarding uptake of Fe, Mn, Zn and Cu by haulm are reported in table 43. Fe uptake was significantly influenced due to different treatments. The application of 100 per cent RDF in conjunction with BS @ 5 t ha^{-1} removed significantly higher amount of Fe (1401 g ha^{-1}) which was at par with FYM plus 100 per cent RDF (1284 g ha^{-1}), pressmud plus 100 per cent RDF (1348 g ha^{-1}) BC plus 100 per cent RDF (1347 g ha^{-1}), BS @ 5t ha^{-1} plus 50 percent RDF (1210 g ha^{-1}) and BS plus 100 per cent RDF. In contrast, control treatment removed lowest amount of Fe i.e. 921 g ha^{-1} and statistically it was at par with application BC plus half recommended doses (1102 g ha^{-1}) and BS application 2.5 t ha^{-1} plus 50 per cent RDF (1037 g ha^{-1}). In remaining treatments Fe uptake varied between 1182 and 1195 g ha^{-1}. The Mn uptake by haulm varied from 170 to 272 g ha^{-1}. Barring, the control treatment (170.3 g ha^{-1}) and application of 2.5 t ha^{-1} BS plus 50 per cent RDF (T_7), all other treatments behaved practically same with respect to Mn removal. The pattern of Zn removal was almost similar to that of Fe and it was varied between 108.7 and 179.1 g ha^{-1}. In case of Cu uptake, all the treatments behaved statistically same, except those of control (68.7 g ha^{-1}), biosludge @ 2.5 t ha^{-1} plus 50 per cent RDF (87.90 g ha^{-1}) and biocompost plus 50 per cent RDF (97.0 g ha^{-1}).

4.2.2.2.4 Heavy metal content

An appraisal of data (Table 44) expounded that concentration of Ni, Pb, Cd, and Co in groundnut pod and haulm was not significantly influenced by different treatments. However, their concentration in pod varied from 0.544 to 0.558, 0.645 to 0.650, 0.013 to 0.016 and 0.429 to 0.441 mg kg^{-1} Ni, Pb, Cd and Co, respectively. While in haulm it ranged between 0.676 to 0.695 mg Ni kg^{-1}, 0.787 and 0.796 mg Pb kg^{-1}, 0.019 and 0.021 mg Cd kg^{-1} and 0.719 and 0.723 mg Co kg^{-1}.

4.2.2.3 Soil changes

4.2.2.3.1 Physico-chemical properties

The data presented in table 45 indicated that the residual effect of different types of solid waste with half and full doses of fertilizers did not influence the soil reaction values. But the electrical conductivity value due to different treatment was found to be significant. The maximum was observed (0.32 dSm^{-1}) at 100 % RDF with biological sludge application, (T_3) which was at par with T_2, T_7 and T_8. It was minimum (0.18 dSm^{-1}) at control. As like the pH value, the organic carbon status of the soil after harvest of groundnut was also recorded statistically same due to different treatments.

4.2.2.3.2 Available major nutrients

The available N varied from 196 kg ha^{-1} at control to 244 kg ha^{-1} at T_3 (Table 46). The latter treatment was statistically at par with T_4 and T_6. Like wise, the former treatment also practically same with 50% RDF in conjunction with application of solid wastes (T_7, T_8, T_9, T_{10} and T_{11}).

As like the available N, P nutrient status was also found significant due to different treatments. The trend of P nutrient status in the soil was more or less similar to available N. In this case also the maximum value (37.40 P_2O_5 kg ha^{-1}) was recorded at T_3 treatments but it was at par with T_4, T_5 and T_6 treatments. Yet, all these treatments were significantly superior to control.

Table 44. Residual effect of different industrial solid wastes with graded fertilizer levels on some heavy metal content in groundnut pod and haulm.

Treatments	Pod (mg kg^{-1})				Haulm (mg kg^{-1})			
	Ni	Pb	Cd	Co	Ni	Pb	Cd	Co
T_1=Control-100 % RDF	0.554	0.645	0.013	0.429	0.676	0.787	0.019	0.719
T_2=BS 2.5t/ha +100%RDF	0.550	0.648	0.014	0.436	0.689	0.788	0.020	0.721
T_3=BS 5t/ha +100%RDF	0.558	0.650	0.015	0.441	0.695	0.790	0.021	0.723
T_4=FYM 5t/ha +100%RDF	0.550	0.646	0.015	0.436	0.687	0.788	0.020	0.721
T_5=PM 5t/ha +100%RDF	0.553	0.647	0.014	0.437	0.682	0.787	0.020	0.721
T_6=BC 5t/ha +100%RDF	0.555	0.647	0.016	0.435	0.682	0.789	0.019	0.722
T_7=BS 2.5t/ha +50%RDF	0.553	0.647	0.015	0.434	0.683	0.788	0.019	0.720
T_8=BS 5t/ha +50%RDF	0.555	0.650	0.016	0.438	0.684	0.789	0.020	0.722
T_9=FYM 5t/ha +50%RDF	0.556	0.647	0.015	0.438	0.681	0.790	0.019	0.723
T_{10}=PM 5t/ha +50%RDF	0.556	0.647	0.015	0.439	0.680	0.789	0.020	0.721
T_{11}=BC 5t/ha +50%RDF	0.554	0.648	0.016	0.438	0.686	0.788	0.020	0.721
S.Em ±	0.006	0.004	0.001	0.003	0.005	0.003	0.001	0.003
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS

Table 45. Residual effect of different industrial solid wastes with graded fertilizer levels on physico-chemical characteristics of the soil

Treatments	Physico-chemical characteristics		
	pH (1:2.5)	EC (1:2.5) dSm^{-1}	Organic carbon (%)
T_1=Control- 100 % RDF	8.14	0.18	0.36
T_2=BS 2.5t/ha +100%RDF	8.06	0.29	0.43
T_3=BS 5t/ha +100%RDF	8.04	0.32	0.52
T_4=FYM 5t/ha +100%RD	8.24	0.22	0.48
T_5=PM 5t/ha +100%RDF	8.15	0.26	0.47
T_6=BC 5t/ha +100%RDF	8.18	0.20	0.49
T_7=BS 2.5t/ha +50%RDF	8.06	0.29	0.43
T_8=BS 5t/ha +50%RDF	8.05	0.31	0.50
T_9=FYM 5t/ha +50%RDF	8.15	0.22	0.45
T_{10}=PM 5t/ha +50%RDF	8.14	0.23	0.47
T_{11}=BC 5t/ha +50%RDF	8.11	0.21	0.47
S.Em ±	0.03	0.01	0.03
CD at 5%	NS	0.03	NS

Table 46. Residual effect of different industrial solid wastes with graded fertilizer levels on available major nutrient of the soil

Treatments	Available major nutrients (kg ha^{-1})		
	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
T_1=Control- 100 % RDF	196	24.95	558
T_2=BS 2.5t/ha +100%RDF	224	29.09	599
T_3=BS 5t/ha +100%RDF	244	37.40	630
T_4=FYM 5t/ha +100%RDF	231	35.41	638
T_5=PM 5t/ha +100%RDF	224	34.41	692
T_6=BC 5t/ha +100%RDF	230	37.35	705
T_7=BS 2.5t/ha +50%RDF	211	24.51	583
T_8=BS 5t/ha +50%RDF	212	23.42	588
T_9=FYM 5t/ha +50%RDF	206	25.98	601
T_{10}=PM 5t/ha +50%RDF	210	24.36	628
T_{11}=BC 5t/ha +50%RDF	198	24.48	615
S.Em ±	6.00	1.34	15
CD at 5%	17.00	3.88	43

The available K status value varied from 558 K_2O kg ha^{-1} at control to 705 K_2O kg ha^{-1} at application of biocompost and 100 % RDF (T_6). Though T_5 treatment was at par with T_6 and significantly higher than that of any other treatments. The available K value at 100 % RDF with biological sludge (T_3) and FYM (T_4) were 630 and 638 K_2O kg ha^{-1}. Both of this values were at par between themselves and statistically same as that of T_{10} and T_{11} and significantly superior to control. There was also no statistically difference among the treatment of T_1, T_7, T_8 and T_9.

4.2.2.3.3 DTPA extractable micronutrients

The content Fe, Mn, Zn and Cu determined after harvesting of groundnut (residual effect) are presented in table 47. The treatment differences were conspicuous with relation to content of Fe and Zn, whereas, Mn and Cu content did not differ significantly due to different treatments.

The significantly higher content of Fe was observed with application of biological sludge alongwith 100 % RDF (11.88 mg kg^{-1}), which were at par with T_6 (11.66 mg kg^{-1}), T_8 (11.21 mg kg^{-1}), T_4 (10.84 mg kg^{-1}) and T_2 (10.76 mg kg^{-1}). All these treatments were significantly superior to control (8.98 mg kg^{-1}). The treatments T_7, T_9 and T_{10} also accumulated more Fe as compared to control. So far as Zn content in soil is concerned, it was differed significantly due to different treatments. Application of biological sludge alongwith 100 per cent RDF (T_3) to main crop registered significantly higher Zn content than other treatments under test except, T_2, T_4, T_6 and T_8. The rest of treatments were observed practically same, in respect to Zn content in soil.

4.2.2.3.4 DTPA extractable heavy metals

The data presented in table 48 indicated that different types of solid waste with full and half doses of fertilizer did not evoke any significant influence on

Table 47. Residual effect of different industrial solid wastes with graded fertilizer levels on DTPA extractable micronutrient of the soil

Treatments	DTPA extractable micro nutrients (mg kg^{-1})			
	Fe	Mn	Zn	Cu
T_1=Control-100 % RDF	8.98	13.13	0.46	2.24
T_2=BS 2.5t/ha +100%RDF	10.76	14.48	0.63	2.68
T_3=BS 5t/ha +100%RDF	11.88	15.03	0.69	2.71
T_4=FYM 5t/ha +100%RDF	10.84	13.25	0.62	2.40
T_5=PM 5t/ha +100%RDF	11.04	14.53	0.54	2.39
T_6=BC 5t/ha +100%RDF	11.66	15.51	0.58	2.41
T_7=BS 2.5t/ha +50%RDF	10.50	15.13	0.42	2.36
T_8=BS 5t/ha +50%RDF	11.21	14.82	0.60	2.59
T_9=FYM 5t/ha +50%RDF	10.47	13.46	0.56	2.32
T_{10}=PM 5t/ha +50%RDF	10.50	13.73	0.59	2.37
T_{11}=BC 5t/ha +50%RDF	10.71	13.01	0.55	2.51
S.Em ±	0.42	0.77	0.04	0.17
CD at 5%	1.21	NS	0.11	NS

Table 48. Residual effect of different industrial solid wastes with graded fertilizer levels on DTPA extractable heavy metal of the soil

Treatments	DTPA extractable heavy metals (mg kg^{-1})			
	Ni	Cd	Pb	Co
T_1=Control-100 % RDF	0.78	0.070	0.79	0.89
T_2=BS 2.5t/ha +100%RDF	0.83	0.070	0.80	0.89
T_3=BS 5t/ha +100%RDF	0.93	0.073	0.93	0.93
T_4=FYM 5t/ha +100%RDF	0.87	0.078	0.85	0.97
T_5=PM 5t/ha +100%RDF	0.89	0.073	0.86	0.91
T_6=BC 5t/ha +100%RDF	0.89	0.083	0.90	0.97
T_7=BS 2.5t/ha +50%RDF	0.80	0.073	0.77	0.95
T_8=BS 5t/ha +50%RDF	0.91	0.078	0.87	0.94
T_9=FYM 5t/ha +50%RDF	0.82	0.070	0.74	0.93
T_{10}=PM 5t/ha +50%RDF	0.84	0.075	0.80	0.92
T_{11}=BC 5t/ha +50%RDF	0.80	0.078	0.90	0.89
S.Em ±	0.04	0.005	0.04	0.04
CD at 5%	NS	NS	NS	NS

the contents of Ni, Cd, Pb and Co in the soil after the harvest of residual groundnut

4.2.2.3.5 Physical properties of the soil

A perusal of data presented in table 49 revealed that different types of solid waste with full and half doses of recommended fertilizer did not exert any significant influence on bulk density and water stable aggregate of soil after harvest of groundnut. However, the bulk density of soil was reduced from 1.50 Mg m^{-3} at control to 1.43 Mg m^{-3} at T_3. Similarly water stable aggregate increased from 74.46 per cent at control to 78.0 per cent at T_8 treatment.

Table 49. Effect of different industrial solid wastes and graded fertilizer levels on physical properties of the soil (After harvest of groundnut crop)

Treatments	Bulk density(Mg m^{-3})	Water stable aggregate (%) > 0.25mm
T_1=Control- 100 % RDF	1.50	74.46
T_2=BS 2.5t/ha +100%RDF	1.45	75.00
T_3=BS 5t/ha +100%RDF	1.43	77.98
T_4=FYM 5t/ha +100%RDF	1.44	76.70
T_5=PM 5t/ha +100%RDF	1.45	75.95
T_6=BC 5t/ha +100%RDF	1.45	77.45
T_7=BS 2.5t/ha +50%RDF	1.45	75.75
T_8=BS 5t/ha +50%RDF	1.44	78.00
T_9=FYM 5t/ha +50%RDF	1.45	77.00
T_{10}=PM 5t/ha +50%RDF	1.45	76.00
T_{11}=BC 5t/ha +50%RDF	1.47	78.10
S.Em $\pm$	0.01	1.888
CD at 5%	NS	NS

DISCUSSION

V DISCUSSION

The present investigation was carried out in two phases. In first phase, two effluents water with 50, 75and 100 per cent recommended dose of fertilizer were ascertained as direct and cumulative effect on onion and fodder maize crop, respectively. In this study observations viz., fresh and dry matter yield of respective crop, nutrient content and uptake as well as heavy metal content were recorded. Physical properties of the soil, available nutrients and heavy metal content in soil were also recorded. Whereas, in the second part two field experiment with the different solid wastes (biological sludge, pressmud, biocompost) and one treatment of FYM for assessing direct and residual effect on yield performance of cabbage and summer groundnut, respectively were conducted. In this experiment, some yield attributing character, dry matter production, nutrient content and uptake as well as some heavy metal concentration in plant and soil were recorded. Soil property changes due to addition of wastes were also recorded. In the preceding chapter the results have been described. Here, the highlights of the results obtained in the present studies are discussed alongwith scientific reasoning through quoting the pertinent research works carried out earlier. For convenience, whole discussion has been sub divided into following parts.

5.1 Feasibility study of fertilizer reduction through effluents water

5.1.1 Direct effect on onion crop

5.1.1.1 Fresh and dry matter yield

5.1.1.2 Nutrient content and uptake

5.1.1.3 Heavy metal content

5.1.1.4 Soil changes.

5.1.2 Cumulative effect on fodder maize crop

5.1.2.1 Fresh and dry matter yield

5.1.2.2 Nutrient content and uptake

5.1.2.3 Heavy metal content

5.1.2.4 Soil changes

5.2 Feasibility study of fertilizer reduction through solid wastes

5.2.1 Direct effect on cabbage crop

5.2.1.1 Fresh and dry matter yield

5.2.1.2 Nutrient content and uptake

5.2.1.3 Heavy metal content

5.2.1.4 Soil changes

5.2.2 Residual effect on summer groundnut crop

5.2.2.1 Dry matter yield

5.2.2.2 Nutrient content and uptake

5.2.2.3 Heavy metal content

5.2.2.4 Soil changes

5.1 Feasibility study of fertilizer reduction through effluents water

5.1.1 Direct effect on onion crop

5.1.1.1 Fresh and dry matter yield

The pot culture experiment conducted to explore the feasibility of reduction in the fertilizer dose to onion with the effluents water (RIL and UPL) has clearly indicated that 50 per cent of the recommended dose of fertilizer nutrients can be saved. (Fig.1). It is also seen that at 100 per cent of fertilizer application and use of both effluent water the bulb yield could be increased more than with canal water. Similar to bulb, the yield of leaves was also same at 100 per cent recommended dose with normal water and 50 per cent recommended dose with effluent water. Thus, it is clearly seen that the use of both effluent water as a source of irrigation, provides not only water to the

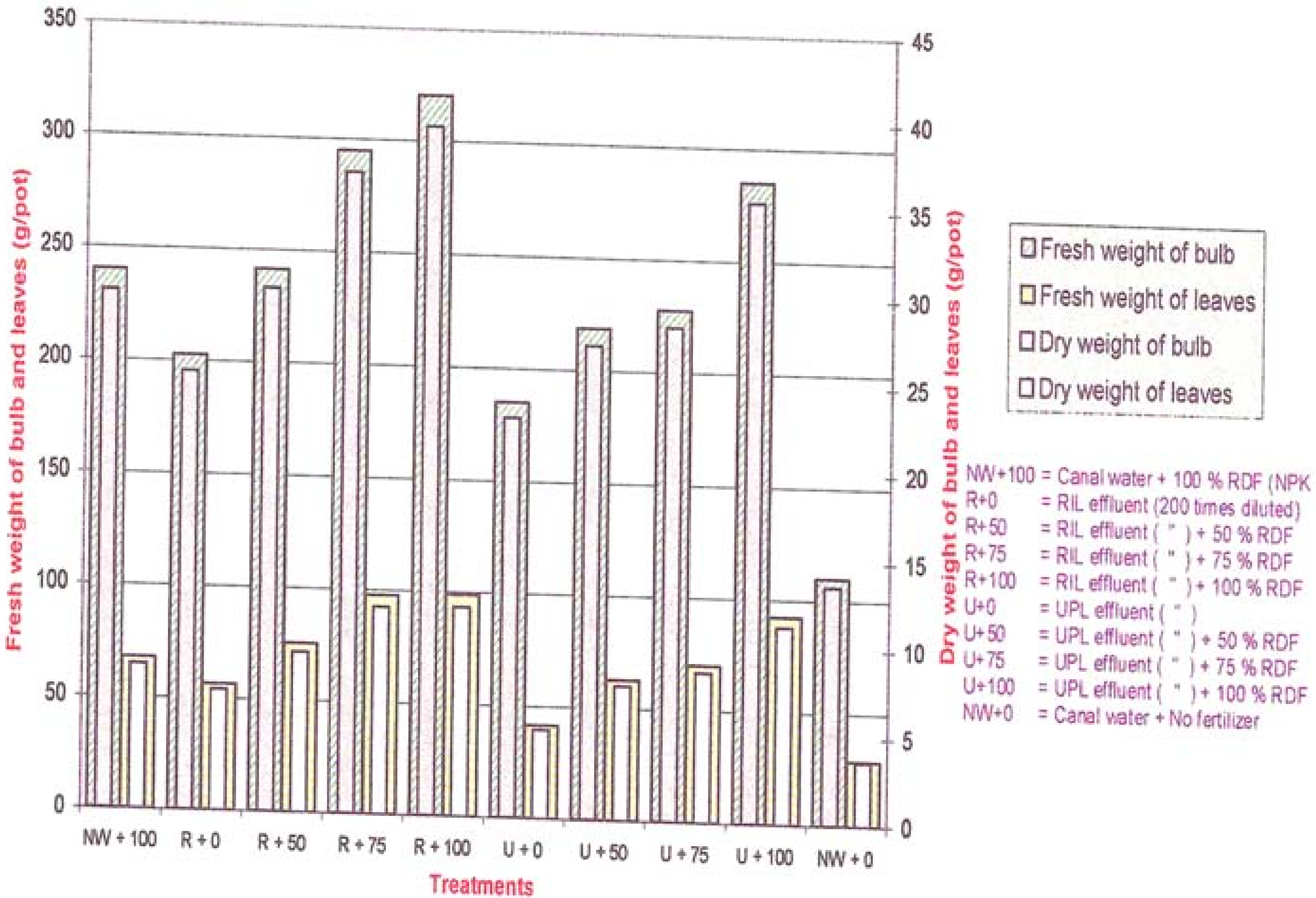


Fig. 1 : Direct effect of diluted industrial effluent and graded RDF on fresh and dry weight of onion bulb and leaves

plants but also increases the nutrient availability to the plants and efficiency of the fertilizer applied. Bajpai and Dua (1972) reported similar type of beneficial effect of effluent water in saving the fertilizer. They stated that 200 kg N ha^{-1} was saved due to use of diluted spent wash for sugar cane. Use of daily effluents was also observed to result in saving of fertilizer for different crop (Dmitrieva *et al.*, 1979 and Jensen, 1981a). Similarly Jensen (1981b) and Smith and Hayden (1984) observed that the Potato factory effluents water could reduce the fertilizer requirement of potato and corn crops. Zalawadia and Raman (1994) observed that, diluted distillery effluents irrigation curtailed 25 per cent of fertilizer requirement for sorghum crop under pot condition. Malti *et al.* (1998) obtained the similar yield of rice irrigating with the diluted paper mill effluents and normal irrigation water. The sewage water usage reduces the fertilizer requirement of various crops were also reported by many workers. (Feign *et al.*, 1978 for rhode grass, Jayaraman, 1988 in case of hybrid bajra, Marecos *et al.*, 1989 in case of sorghum crop and Tiwari *et al.*, 1996 for rice crop).

5.1.1.2 Nutrient content and uptake

The nutrients N, P, K Ca, Mg, S, Fe, Mn, Zn, Cu and heavy metals like Ni, Cd, Pb, and Co content of bulb and leaves were determined and their uptake was computed and presented in the preceding chapter. Data depicted in figure 2 and 3 showed that the concentration of major nutrients (N, P and K) of both bulb and leaves increased with increase in fertilizer dose with both effluents water irrigation. The contents (N, P and K) recorded at 50 per cent recommended dose with both effluents water practically remained same with the content of 100 per cent recommended dose and irrigated with normal water. This may be due to higher concentration of above nutrients in effluents water. The finding corroborates the report of Zabek (1976) for root crops, green fodder, wheat grain and rapeseed and Dmitrieva *et al.* (1979) for different crops with dairy

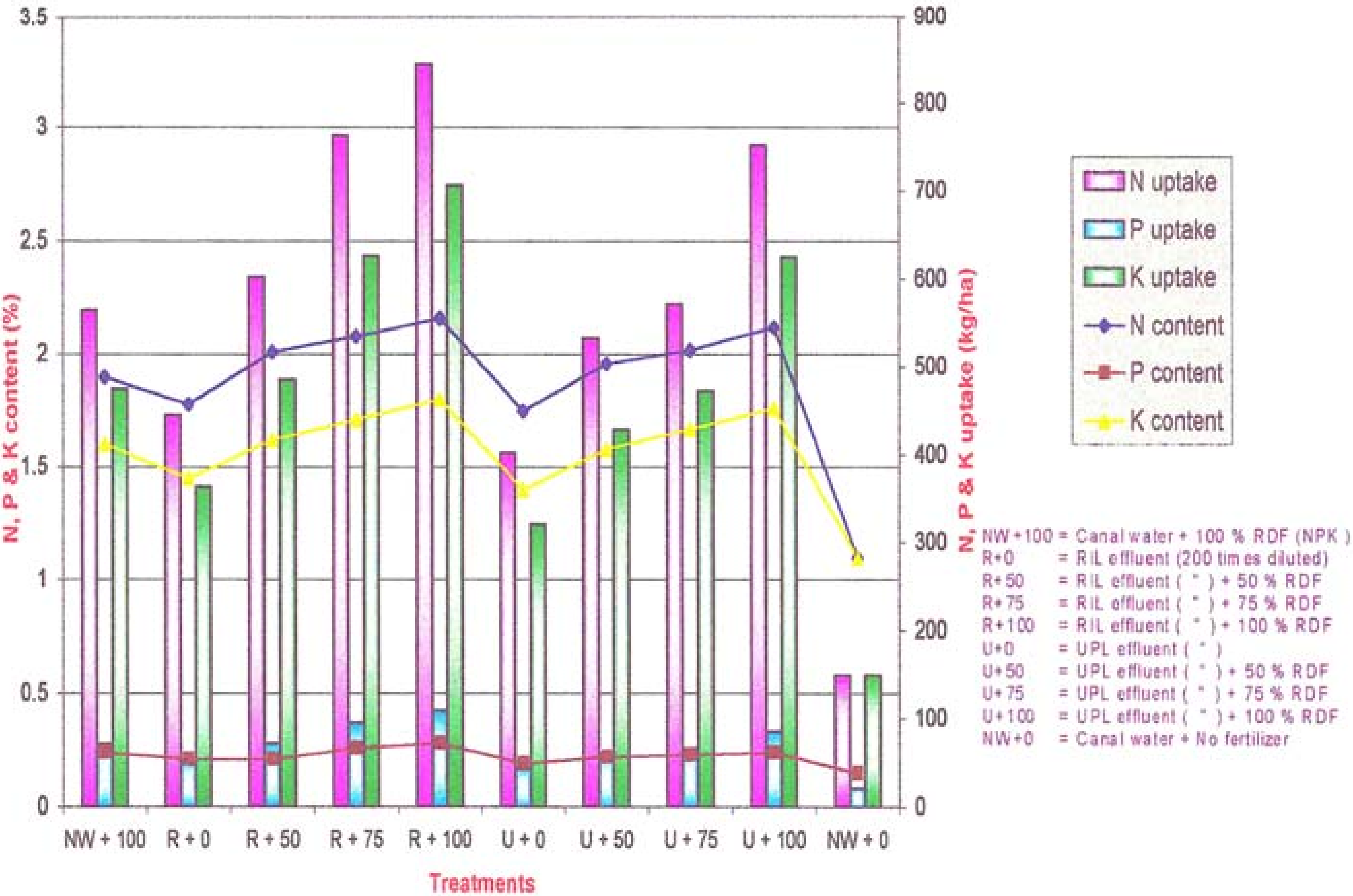


Fig. 2 : Direct effect of diluted industrial effluent and graded RDF on major nutrient content and uptake by onion bulb

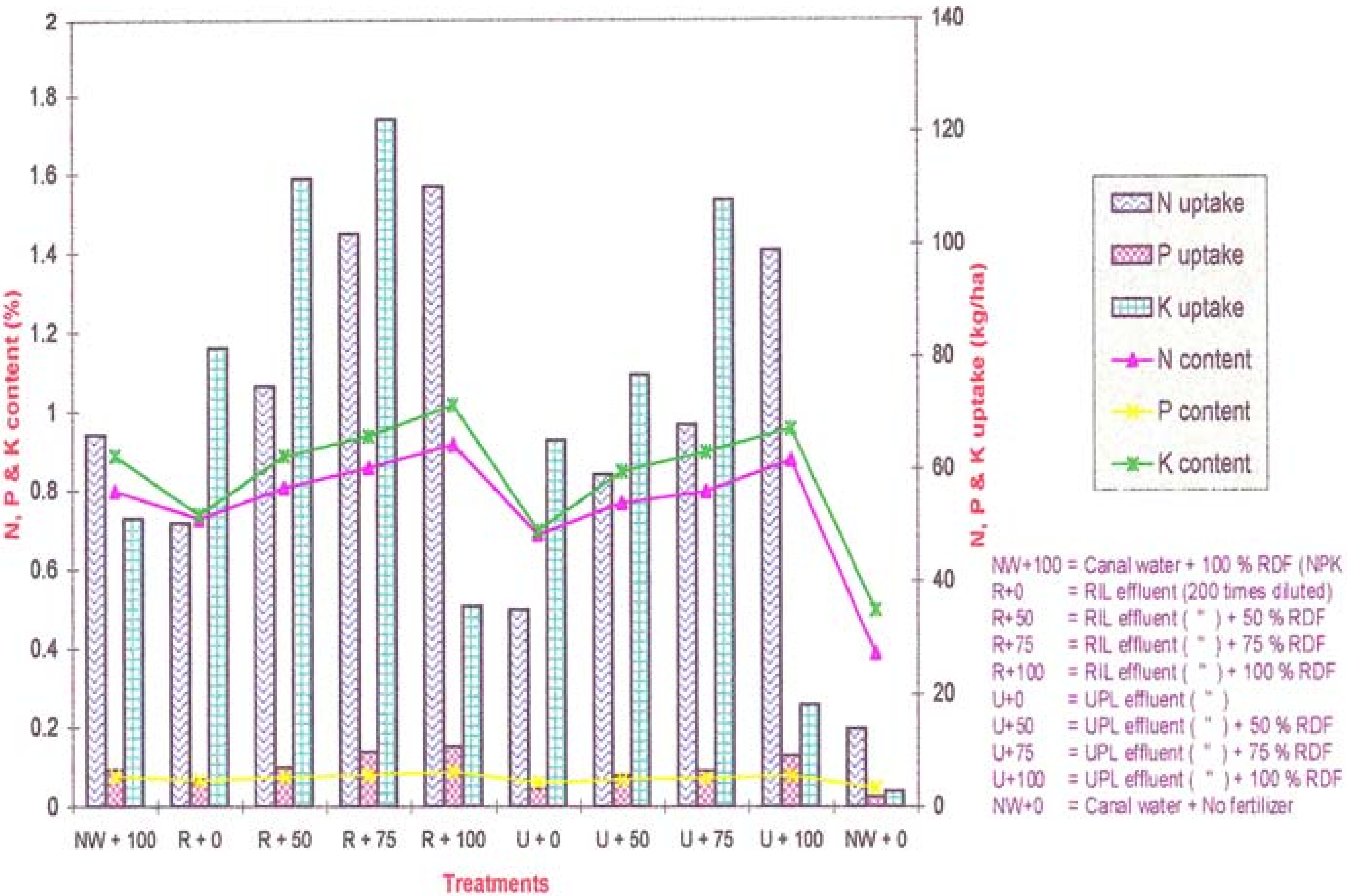


Fig. 3 : Direct effect of diluted industrial effluent and graded RDF on major nutrient content and uptake by onion leaves

effluents. The results are also akin with the findings of Zalawadia and Raman (1994) for sorghum crop using distillery effluents water.

The uptake of N by bulb and leaves increased with increasing levels of fertilizer. But there was not much difference between 50 per cent of fertilizer doses alongwith either RIL or UPL effluents and 100 per cent fertilizer with canal water. The same trend was observed in the case of P and K uptake by bulb and leaves (Fig. 2 and 3). The applied fertilizer response was obtained up to 75 per cent RDF in case of RIL effluents, whereas, in case of UPL effluents these response to the extent of 100 per cent fertilizer application. The fact is more pronounced when the fertilizers use efficiency was worked out as the amount of dry matter produced per unit quantity of nutrients. It is seen that the value was maximum 37.11 with 50 per cent fertilizer alongwith RIL effluents and 29.83 with 50 per cent RDF alongwith UPL effluents (Table 50). With 100 per cent fertilizer nutrients applied with canal water, the figure was only 17.56. An increase in the uptake of N, P and K by onion crop under both the effluent irrigation treatments could be attributed to the addition of above nutrients through effluents resulting in higher growth and ultimately yield and the nutrient uptake. Such beneficial effect of increased nutrient uptake under effluents irrigation were reported by Zabek (1976) in root crops, green fodder, wheat grain, Dmitrieva *et al.* (1979) in different crops with dairy effluents, Ajmal and Khan (1983) in bean with electro plating factory effluents and Zalawadia *et al.* (1994) in sorghum with distillery effluents.

Secondary nutrients such as Ca and Mg concentration in bulb were not affected by effluents irrigation. However, Ca concentration in leaves was affected due to effluents irrigation, though S content in both bulb and leaves was greatly influenced due to effluents irrigation (Table 8 and 9). This might be due to fact that effluents water contained more S than Ca and Mg consequently, their

Table 50 . Fertilizer use efficiency of onion crop

Treatments Effluent + RDF (%)	Fertilizers Added (g pot^{-1})	Additional yield of crop over absolute control (g pot^{-1})			Fertilizers use efficiency (%)		
		bulb	leaves	total	bulb	leaves	total
NW+O	0.00	--	--	--	--	--	--
NW+100	1.178	16.03	4.65	20.68	13.61	3.95	17.56
R+O	0.00	11.19	3.30	14.79	--	--	--
R+50	0.589	16.31	5.55	21.86	27.69	9.42	37.11
R+75	0.884	23.06	8.17	31.33	26.08	9.35	35.43
R+100	1.178	15.77	8.36	34.13	21.88	7.09	28.97
U+0	0.00	9.29	1.47	10.76	--	--	--
U+50	0.589	13.51	4.06	17.57	22.94	6.89	29.83
U+75	0.884	14.63	4.94	19.57	16.55	5.59	22.14
U+100	1.178	21.86	7.64	29.5	18.56	6.49	25.05

concentration in plant part varied according to effluents content of these element.

The uptake pattern of Ca and Mg were almost similar to that of N, P and K uptake. Whereas, the uptake pattern of S was reverse. The uptake of S in UPL effluents was more as compared to RIL effluents, as S content in UPL effluents was more as compared to RIL effluents. Increased Ca, Mg and S uptake under both effluent irrigation was mainly due to addition of these nutrients through effluents irrigation. These findings are akin to those of Dmitrieva *et al.* (1979) in different crop with dairy effluents. In contrary, Zabek (1976) noted a decrease Ca and Mg content of root crops due to use of dairy effluents.

In case of micronutrients content Fe, Mn, Zn and Cu were found significant in bulb and leaves (Table 10 and 11). The values of Fe, Mn, Zn and Cu concentration were increased under RIL and UPL effluent irrigation as compared to normal water irrigation. Addition of fertilizer further increased such value both in bulb and leaves under both effluents water irrigation. This may be due to effluents water content of such metals.

For assessing the treatment differences with respect to micro nutrient removal, total uptake of all the micronutrient was worked out and reported in table 51. The results revealed that among the treatment tested, removal of all the micronutrients (Fe, Mn, Zn and Cu) was considerably higher with R+100 (RIL effluents irrigated with 100 per cent RDF). In general, RIL effluents irrigation treatments removed higher nutrients than UPL effluents irrigation treatments. Of the three fertilizer doses, 100 per cent RDF removed higher micro nutrients which was followed by 75 per cent doses in both the effluents i.e. RIL and UPL irrigation treatment. It is also seen that the removal of Fe, Mn,Cu and Zn under R+50 treatment was slightly higher as compared to NW+100. Whereas, the

Table 51. Direct effect of diluted industrial effluents and graded fertilizer levels on total micronutrient uptake by onion

Treatments	Total uptake (g pot^{-1}			
	Fe	Mn	Zn	Cu
NW+100	2.91	1.45	0.93	0.43
R+0	10.94	1.35	0.75	0.34
R+50	3.60	2.21	1.42	0.55
R+75	4.27	2.92	1.76	0.67
R+100	4.60	2.99	1.88	0.69
U+0	1.97	1.10	0.61	0.30
U+50	2.84	1.76	1.04	0.45
U+75	2.98	1.78	1.10	0.47
U+100	3.87	2.35	1.41	0.63
NW+O	0.51	0.20	0.24	0.07

removal of such micronutrient under U+50 was marginally lower as compared to NW+100. Utilization of Fe, Mn, Zn and Cu at R+100 was increased by 58.08, 106.2, 102.15 and 60.46 per cent, respectively over NW+100. Similarly, the corresponding utilization of such nutrients at U+100 increased by 32.99, 62.06, 51.16 and 46.51 per cent, respectively. An increase in the micronutrient uptake of Onion registered under the effluents irrigation treatments could be attributed to the addition of above nutrients through effluents, which enhanced the crop growth consequently, increased the uptake. The results are in accordance with those reported by Fazeli *et al.* (1991); Singh *et al.* (1991) and Niedzwiecki *et al.* (2000).

5.1.1.3 Heavy metal content

Though the concentration of heavy metal in onion bulb and leaves was found to be significant yet, most of the treatment remained statistically at par except NW+O treatment, which contained very low concentration of heavy metal (Table 12). It is mainly due to the fact that diluted effluents water used in present study contained very low concentration of such metals. Besides, the concentration found in onion bulb and leaves are below the phytotoxicity limits as reported by Alloway (1990) for Cd (0.1– 2.4 mg kg^{-1}), Sauerbeck (1982) for Pb (10 mg kg^{-1}). Gupta (1994) concluded that of non-essential heavy metals added at the rate of 40 mg kg^{-1}, Pb and Ni had the least adverse effect on the yield of green gram, black gram and pigeon pea while Cd was more toxic.

5.1.1.4 Soil changes

The physico-chemical properties like, soil reaction, electrical conductivity and organic carbon status of the soil under effluents irrigation were affected (Table 13). In RIL effluents irrigation the pH value varied from 7.71 to 7.79 while in UPL effluents effluents irrigation these pH value ranged between 7.95 to 8.00. Soil reaction value after 100 per cent RDF with normal water irrigation

(8.13) was higher than that of any dose of fertilizer with both effluents water. It seems that effluents irrigation decreases the soil pH value because of RIL effluents was acidic in nature and low pH under UPL effluents might be due to higher content of SO_4^{-2} ions. The results are in accordance with those reported by Singh (1961) with spent wash, Ajmal and Khan (1984a) with brewery effluent, Sivaswami (1991) with tannery effluent, Bansal *et al.* (1992) with industrial waste water.

The electrical conductivity value increased remarkably with the usage of both effluent water when compared to normal water. Though the UPL effluents usage tended to increase more electrical conductivity as compared to RIL effluents water. These results are in accordance with those reported by Subba Rao (1972); Ajmal and Khan (1984a); Stahl and Williams (1986); Somawanshi and Yadav (1990); Devarajan and Oblisami (1995); Pathak *et al.* (1998) and Achari *et al.* (1999).

The organic carbon content increased with both of the effluent irrigation when compared to normal water irrigation. The effluents contained organic material, which was responsible for increasing organic matter in the soil. These results conform to those of Subba Rao (1972); Ajmal *et al.* (1984); Stahl and Williams (1986); Somawanshi and Yadav (1990) and Zalawadia and Raman (1994).

The available N status jumped from 102 ppm with normal water and no fertilizer to 436 and 170 ppm after RIL and UPL effluents irrigation with 100 per cent recommended fertilizer, respectively (Table 14). An increase in the available N status of the soil registered under the both effluent irrigation treatments can be attributed to the addition through effluents which contained an average of 0.042 and 0.055 per cent N. In general, the accumulation of available N was more after RIL effluents irrigation as compared to UPL effluents irrigation even though the former effluents content low nitrogen as compared to latter effluents because of former effluents was acidic in nature whereas, latter was slightly alkaline to alkaline in nature. Fillery and Vlek (1986) have reported higher losses of ammonia in irrigation water of high alkalinity. The pH of the UPL effluents used in present studies was originally 8.23 (before dilution). Besides, higher losses of N through leaching and Volatilization under effluents irrigation particularly at greater concentration has also been reported by Bahirat *et al.* (1989). Increase in nitrogen status of the soil after effluents irrigation was also reported by Zalawadia and Raman (1996); Tiwari *et al.* (1996); Devarajan and Oblisami (1995) and Malti *et al.* (1998).

The available P and K concentration in soil were higher under effluents irrigation. The available P also increased numerically with increases in the fertilizer level in both the effluent water treatments. As like the nitrogen concentration, the available P was also higher after RIL effluents irrigation as compared to UPL effluents irrigation. This may be due to RIL effluents water had a higher content of P. As against P, available K was higher under UPL effluents irrigation as compared to RIL effluents irrigation. It has been due to higher K content in UPL effluents. These results are in agreement with those of Sivaswami (1991); Tiwari *et. al.* (1996); Devarajan and Oblisami (1995) and Malti *et al.* (1998).

The DTPA extractable Fe, Mn, Zn and Cu in soils receiving canal irrigation with 100 per cent RDF was 9.80, 17.40, 0.96 and 3.68 mg kg^{-1}, respectively whereas, corresponding values for RIL effluents irrigated soil with 100 per cent RDF were 12.92, 19.32, 1.23 and 3.66 mg kg^{-1}, respectively, while corresponding values for UPL at the same level of fertilizer were 12.98, 31.36, 1.16 and 3.68 mg kg^{-1}, respectively (Table 15). It seems that RIL effluents (R+100) increased the DTPA extractable Fe, Mn and Zn by 31.18, 34.0 and 28.0

per cent, respectively and that of UPL effluents (U+100) increased DTPA extractable Fe, Mn and Zn by 24.28, 80.22 and 20.83 per cent, respectively over 100 per cent RDF alongwith canal water. The Cu concentration was highest at 75 per cent RDF at both effluents water treatments, there after it decreased. The increase in DTPA extractable micronutrients was mainly due to the presence of these metal ions in both the effluent water. Increased micronutrients status due to effluents irrigation was earlier reported by Totawat (1991) in case of Fe, Mn, Zn and Cu, Sivaswami (1991) in case of Mn and Zn. However, Singh *et al.* (1991) noted a decrease in concentration of Fe, Mn and Zn in their study.

Among the four heavy metals studied in the present investigation, only Ni concentration in the soil was of great concern. Ni concentration increased from 0.79 mg kg^{-1} to 0.92 mg kg^{-1} in RIL effluents (Table 16). Among the two effluents, RIL effluents irrigation accumulated slightly more Ni content in the soil. However, concentration of this metal in the soil was below the critical limit. The other heavy metal such as Cd and Pb were also under critical concentration limit and they were not increased much as compared to 100 per cent recommended dose of fertilizer alongwith canal water and initial status of the soil. Co concentration in the soil was also increased. It rose from 0.65 mg kg^{-1} at 100 per cent recommended dose plus canal water to 0.96 mg kg^{-1} with UPL effluents irrigation plus 75 % RDF. Considering 0.25 mg kg^{-1} of available Co as the critical limit (Stewart, 1953), it has been established as an essential nutrient for leguminous crops (Ahmad and Evans, 1960 and Reddy and Raj, 1975) and its beneficial effect on other crops has also been reported by Binodkumar *et al.* (2000). It stated that application of 1.0 to 2.5 kg Co ha^{-1} is optimum for maximum forage production of lucerne.

5.1.2 Cumulative effect on fodder maize crop

5.1.2.1 Fresh and dry matter yield

The pot culture experiment on the same pots of first experiment with same treatments was conducted on fodder maize crop for ascertaining the cumulative effect of both effluent water. Data depicted in figure 4 indicated that yields produced at RIL effluents plus 50 per cent RDF and UPL effluents plus 50 per cent RDF were statistically same as that obtained at 100 per cent RDF and irrigated with normal water. The data also indicated that RIL effluents irrigation was responded up to 50 per cent recommended fertilizer application. Whereas, UPL effluents irrigation responded up to 75 per cent recommended fertilizer application. Thus, it is clearly seen that like the direct effect of effluents water, 50 per cent saving of fertilizer was also observed in cumulative effect of effluents water. The above results confirmed that use of both effluents water as a source of irrigation, provided not only water to the plants but also increased the nutrient availability to the plants and efficiency of the fertilizer applied. The pronounced effect of both effluents water on stover yields of maize fodder may be due to the considerable quantities of major, secondary and micronutrients, which are, added alongwith effluents water. Similar type of beneficial cumulative effect of effluents water was reported earlier by Day *et al.* (1976). They reported that yields of cotton, sorghum and barley in rotation and irrigated with waste water did not decrease below these of crops irrigated with well water and applied NPK fertilizer. Yoshika (1981) also substantiates these results in maize and wheat and saving K fertilizer requirement by applying potato starch factory effluents. Bahirat *et al.* (1989) confirmed that total consumption of N requirement can be curtailed by applying fertilizer factory effluents to groundnut and jute crops simultaneously increased yield of 49.8 and 80.4 per cent,

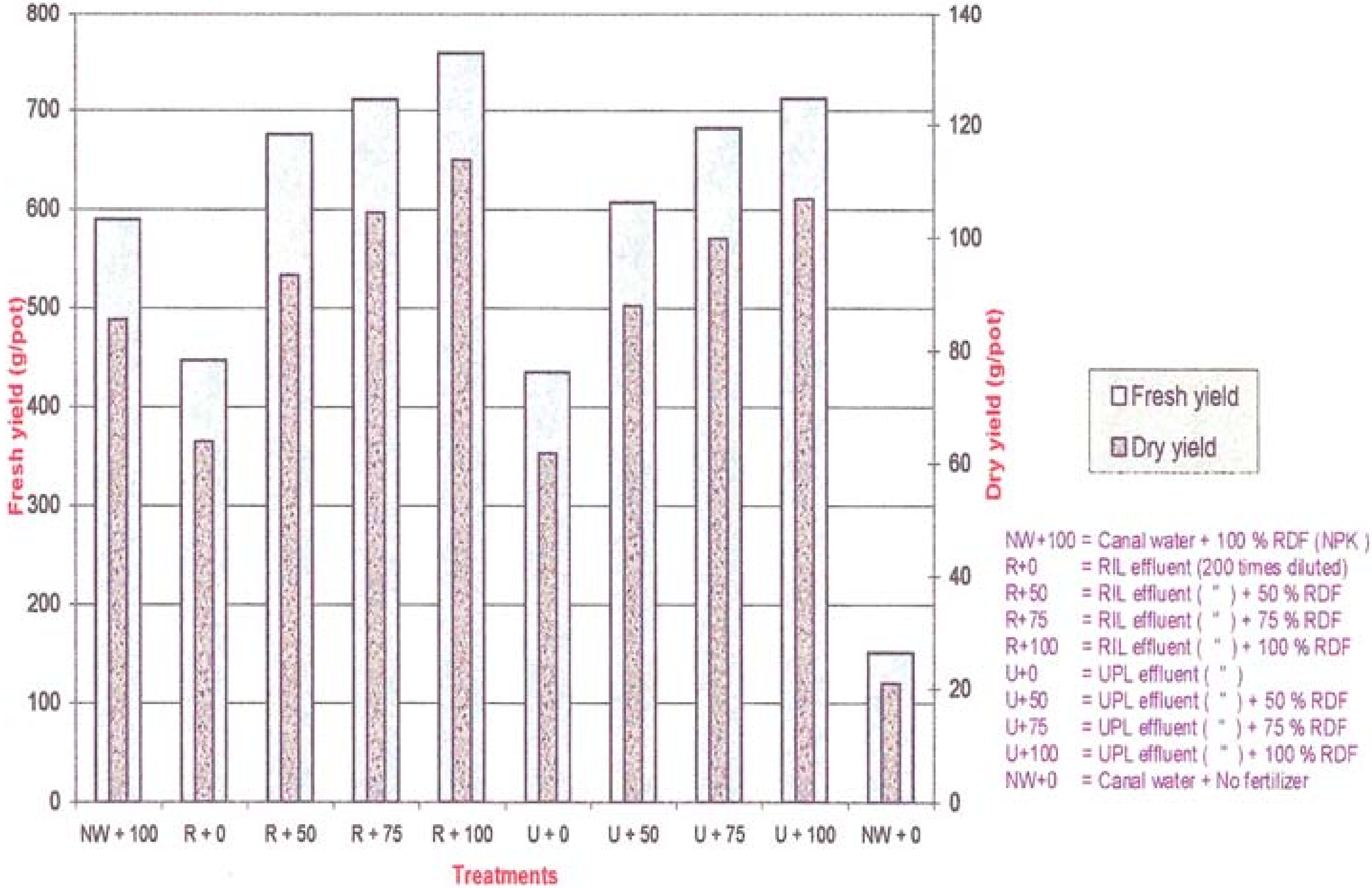


Fig. 4 : Cumulative effect of diluted industrial effluents and graded RDF on fresh and dry yield of fodder maize

respectively. The above results are also in accordance with those of Totawat (1991).

5.1.2.2 Nutrient content and uptake

The nutrients N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu and heavy metals like Ni, Cd, Pb and Co content of fodder maize were determined and their uptake was computed and reported in the preceding chapter. Data depicted in figure 5 indicated that the concentration of major nutrients in plant were recorded more under effluents irrigation as compared to normal water irrigation. It is seen that the contents recorded at 50 per cent RDF along with both effluents water practically remained same with the treatment of 100 per cent RDF but irrigated with normal water.

As the concentration is mainly governed by the pattern of dry matter production, uptakes seem to be more reliable index, which take simultaneously in to account the content and dry matter production. In view of this uptake pattern has been emphasized more than content. The removal of N, P and K nutrients was more at R+50 as compared to NW+100. While removal of these nutrients at U+50 and NW+100 practically remained same. It suggests that effluents irrigation provide the additional nutrients to the crop. This fact is clearer when the fertilizer use efficiency was worked out as the amount of dry matter produced per unit quantity of nutrients. It is seen that value was higher at RIL effluents plus 50 per cent RDF (162.69) and UPL effluents plus 50 per cent RDF (146.50). With 100 per cent fertilizer nutrients but irrigated with canal water the figure was around only 70.48 per cent (Table 52).

The foregoing discussion clearly indicates that 50 per cent saving in fertilizer can easily be achieved through use of diluted effluents water for irrigation purpose. This finding corroborates with the finding of Kumaravelu

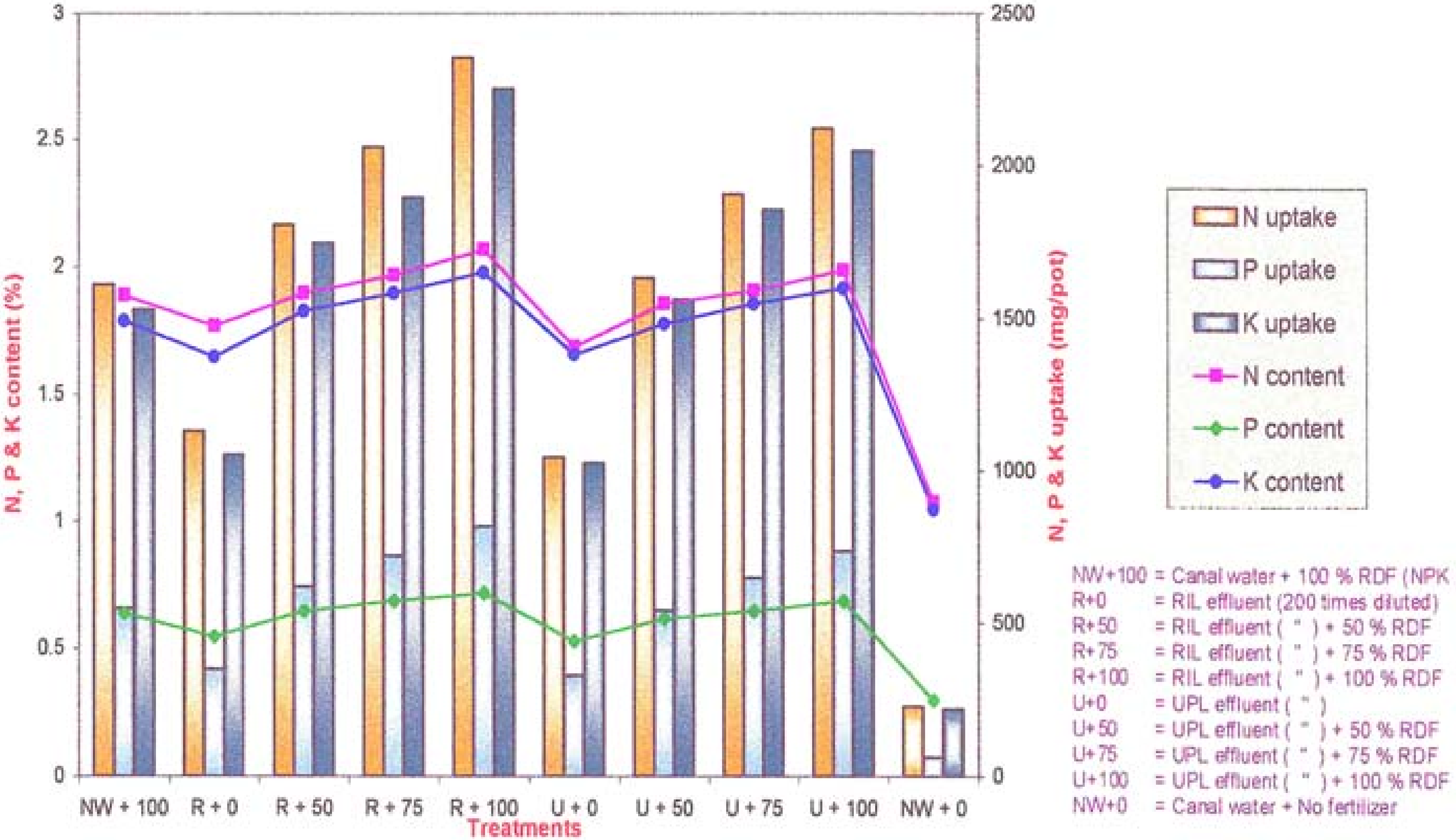


Fig. 5 : Cumulative effect of diluted industrial effluent and graded RDF on major nutrient content and uptake by maize fodder

Table 52. Fertilizer use efficiency of fodder maize crop

Treatments Effluent + RDF (%)	Fertilizers Added (g pot^{-1})	Additional yield of crop over absolute control (g pot^{-1})	Fertilizers use efficiency (%)
NW+O	0.00	--	--
NW+100	0.914	64.42	70.48
R+O	0.00	42.90	--
R+50	0.457	74.35	162.69
R+75	0.685	83.46	121.84
R+100	0.914	92.75	101.48
U+0	0.00	40.82	--
U+50	0.457	66.95	146.50
U+75	0.685	78.84	115.09
U+100	0.914	85.81	93.88

et al. (2000) in finger millet crop. Niedzwiecki *et al.* (2000) reported the similar results by using ammonium sulphate / nitrate spent wash effluents.

The secondary nutrient content was also higher under effluents irrigation as compared to normal water irrigation (Table 19). In most of the treatments, the contents of Ca, Mg and S increased with increase in levels of fertilizer dose. Ca and Mg contents however, slightly higher in RIL effluents but the reverse was true in case of S content. This may be due to the addition of these nutrients alongwith irrigation water.

The Ca Mg and S removal were higher under effluents irrigation treatments as compared to normal irrigation water. The uptake, recorded at 100 per cent RDF plus RIL effluents, of Ca, Mg and S were 45, 40 and 60 per cent, respectively higher than that of normal water irrigation with 100 per cent RDF. The corresponding increases of Ca, Mg and S at the same level of UPL effluents were 28, 38 and 74 per cent, respectively. It is also seen that Ca, Mg and S removal at 50 per cent RDF with both effluents water was about equal to 100 per cent RDF with normal water irrigation. The secondary nutrient uptake increased in effluents irrigation mainly due to beneficial effect of adding these nutrients which increased the dry matter yield and consequently uptake of nutrients.

Data presented in table 20 indicated that concentration of micronutrient like the major and macro nutrients of fodder maize were increased with increase in fertilizer dose and simultaneously under both effluents water irrigation. It is clearly seen that with the same level of recommended dose (100 per cent RDF), the concentration of Fe and Mn increased by two fold, Zn by 1.5 times under RIL effluents irrigation over 100 per cent RDF and irrigated with normal water. Such increases under UPL effluents were lowered but the concentration of Fe, Mn and Zn was higher as compared to normal water irrigation.

Regarding uptake, the results showed that (Table 20) addition of RIL and UPL effluents either with 50 or 75 or 100 per cent recommended doses recorded significant increase in Fe, Mn, Zn and Cu uptake over NW+100 treatment. Irrigation with RIL and UPL effluents alongwith 100 per cent RDF recorded an increase of 19.31 and 10.13 mg pot^{-1} Fe, 3.46 and 2.08 mg pot^{-1} Mn, 1.36 and 0.84 mg pot^{-1} Zn and 0.36 and 0.23 mg pot^{-1} Cu, respectively over 100 per cent RDF and irrigated with normal water. It is seen that the removal of micronutrients under 50 per cent RDF alongwith RIL effluents was much more than that of NW+100. While, under UPL effluents Fe and Mn removal at this recommended doses (50 per cent) was higher but Cu and Zn remained poor at this level. This increase in Fe, Mn, Zn and Cu uptake by maize fodder may be due to better utilization of applied fertilizer by maize crop, higher yields and synergistic effect of diluted effluents water. The results are similar to those reported by Narwal *et al.* (1991).

5.1.2.3 Heavy metal content

Concentration of Ni, Pb, Cd and Co in maize fodder presented in table 21 indicated that the concentration was below the permissible limit. The concentration of Ni ranged from 0.445 to 1.13 mg kg^{-1}. Narwal *et al.* (1991) concluded that lower level of applied Ni to corn crop showed beneficial effect, whereas, at higher level there was sharp reduction in yield. Pb ranged from 0.59 to 1.160 mg kg^{-1}, while Cd and Co varied from not detectable to 0.045 and 0.735 to 1.42 mg kg^{-1}, respectively. All above heavy metals concentrations were below the limits of phytotoxicity (Mortvedt *et al.*, 1991).

5.1.2.4 Soil Changes

5.1.2.4.1 Physico-Chemical properties

The physico-chemical properties like soil reaction, electrical conductivity and organic carbon status of the soil under effluents irrigation were greatly differed to normal water irrigation (Table 22). It is seen that soil reaction under effluents irrigation water was acidic as compared to normal water irrigation. Besides in RIL effluents irrigation the soil pH value was slightly lower than that of UPL effluents irrigation. The lower pH value after RIL and UPL effluents irrigation was mainly due to acidic reaction or sulphate ion present in the effluents water. Similar finding was also reported earlier by Bansal *et al.* (1992). In contrary Kannan and Oblisami (1990); Achari *et al.* (1999) and Malti *et al.* (2000) noted an increase in soil pH value after papermill effluents irrigation. While Pathak *et al.* (1998) reported that there was no change in soil pH value after use of distillery effluents. The above discussion indicates that changes in soil reaction mainly depends on, types of effluents, their concentration and amount to be applied. The soil salinity level was increased considerably after effluents irrigation as compared to normal water irrigation. Further more salinity level was increased more under UPL effluents irrigation as compared to normal water irrigation. There was also increased in salinity level as increases in fertilizer dose. This might be due to the addition of salt alongwith effluents water irrigation. The results are substantiated with the studies conducted by Palaniswami and Ramula (1994); Pathak *et al.* (1998); Achari *et al.* (1999) and Malti *et al.* (2000).

The organic carbon status of the soil was increased numerically after effluent water irrigation. It has been seen that organic carbon status of the soil increased 52 to 54 per cent after effluents irrigation over normal water irrigation. It is mainly due to organic material present in the effluents water. The results corroborate with the results of Kannan and Oblisami (1990); Bansal *et al.* (1990); Palaniswami and Ramula (1994) and Pathak *et al.* (1998).

5.1.2.4.2 Available major nutrients

The available major nutrients in soil jumped greatly after effluents water irrigation as compared to normal water irrigation (Table 22). Further, N availability was more at RIL effluents irrigation as compared to UPL effluents irrigation. As like the N availability the phosphorus availability was also increased after effluents irrigation. An increase was still higher after RIL than that of UPL effluents. Though, the availability of K was higher after UPL effluents irrigation as compared to RIL effluents irrigation. These findings are in close agreement with the report of Bansal *et al.* (1992) in case of N, P and K, Palaniswami and Ramula (1994) in case of K, Schipper *et al.* (1996) in case of N, Pathak *et al.* (1998) in case of K and Achari *et al.* (1999) in case of N and K.

5.1.2.4.3 DTPA extractable micro nutrients

The cumulative effect of DTPA extractable Fe, Mn, Zn and Cu are presented in table 23. The results indicated that DTPA extractable Fe, Mn, Zn and Cu were increased conspicuously after effluents irrigation as compared to normal water irrigation. The concentration of Fe, Mn, Zn and Cu at 100 per cent RDF alongwith RIL and UPL effluents were 23.65 and 15.76, 44.12 and 32.01, 1.28 and 1.20 and 4.44 and 3.86 mg kg^{-1} , respectively. These values of Fe, Mn, Zn and Cu were increased by 121 and47, 96 and 42, 35 and 26 and 29 and 12 per cent, respectively over 100 per cent RDF alongwith canal water. An increase in the DTPA extractable Fe, Mn, Zn and Cu status of the soils registered under both effluents irrigation treatments could be attributed to the addition of the above nutrients through effluents. These results are in conformity with those reported by Kuhad *et al.* (1989); Bansal *et al.* (1992); Achari *et al.* (1999) and Malti *et al.* (2000).

5.1.2.4.4 DTPA extractable heavy metal

Among the four heavy metals, determined in the present investigation, the concentration of Ni and Pb was conspicuous (Table 24). Among the different treatments Ni concentration increased from 0.77 to 0.95 mg kg^{-1}. Sanders *et al.* (1987) reported that no phytotixic effects of Ni on crop yields were measured at the maximum soil concentration of 95 mg kg^{-1}. The concentration of Cd was also below phytotoxic limits (0.8 mg kg^{-1}) as reported by Alloway (1990). The effect of concentration of Pb on direct study of effluents water was not conspicuous, however in the cumulative effect the concentration of Pb increased gradually in the treatment of effluents water treatments but concentration of this metal in the soil was still very lower as compared to critical permissible limits of this metal. The Cobalt concentration was also found more after the effluents irrigation treatments as compared to normal water irrigation treatments. It ranged from 0.66 to 1.08 mg kg^{-1}. Binodkumar *et al.* (2000) stated that application of cobalt @ 1 to 2.5 kg ha^{-1} was beneficial to lucerne crop. The above result indicates that the heavy metal concentration is found below the generalized critical levels. These results are substantiated with the results reported by Kuhad *et al.* (1989) and Niedzwiecki *et al.* (2000).

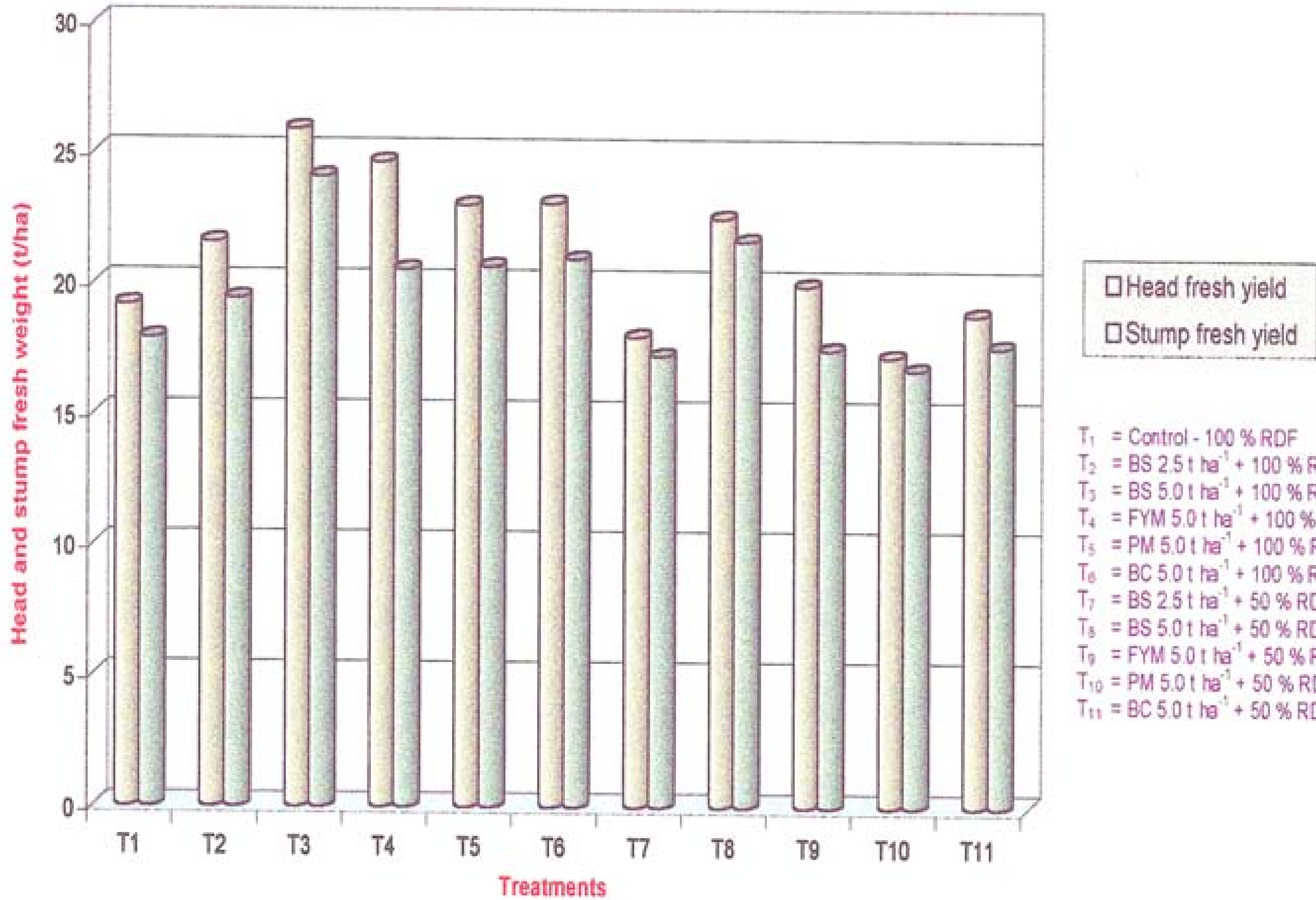
5.2 Feasibility of fertilizer reduction through solid wastes

5.2.1 Direct effect on cabbage crop

To explore the feasibility of saving the fertilizer with usage of solid waste field experiment was conducted at soil and water management farm. The relevant results obtained are presented in preceding chapter. Here, the highlights of the results obtained in the present studies are discussed.

5.2.1.1 Fresh and dry matter yield

The results depicted in figure 6 and 7 indicated that application of all the solid waste increased the fresh and dry matter yield of cabbage head and stump. The maximum cabbage head and stump yield was obtained at application of biological sludge alongwith 100 per cent RDF (T_3), followed by FYM plus 100 per cent RDF (T_4), BC plus 100 per cent RDF (T_6) and PM plus 100 per cent RDF (T_5) in decreasing order. It is also seen that the fresh and dry matter yield of head and stump obtained at 100 per cent RDF (control) was equal to that



T_1 = Control - 100 % RDF
T_2 = BS 2.5 t ha^{-1} + 100 % RDF
T_3 = BS 5.0 t ha^{-1} + 100 % RDF
T_4 = FYM 5.0 t ha^{-1} + 100 % RDF
T_5 = PM 5.0 t ha^{-1} + 100 % RDF
T_6 = BC 5.0 t ha^{-1} + 100 % RDF
T_7 = BS 2.5 t ha^{-1} + 50 % RDF
T_8 = BS 5.0 t ha^{-1} + 50 % RDF
T_9 = FYM 5.0 t ha^{-1} + 50 % RDF
T_{10} = PM 5.0 t ha^{-1} + 50 % RDF
T_{11} = BC 5.0 t ha^{-1} + 50 % RDF

Fig. 6 : Direct effect of different industrial solid wastes with graded RDF on fresh yield of cabbage head and stump

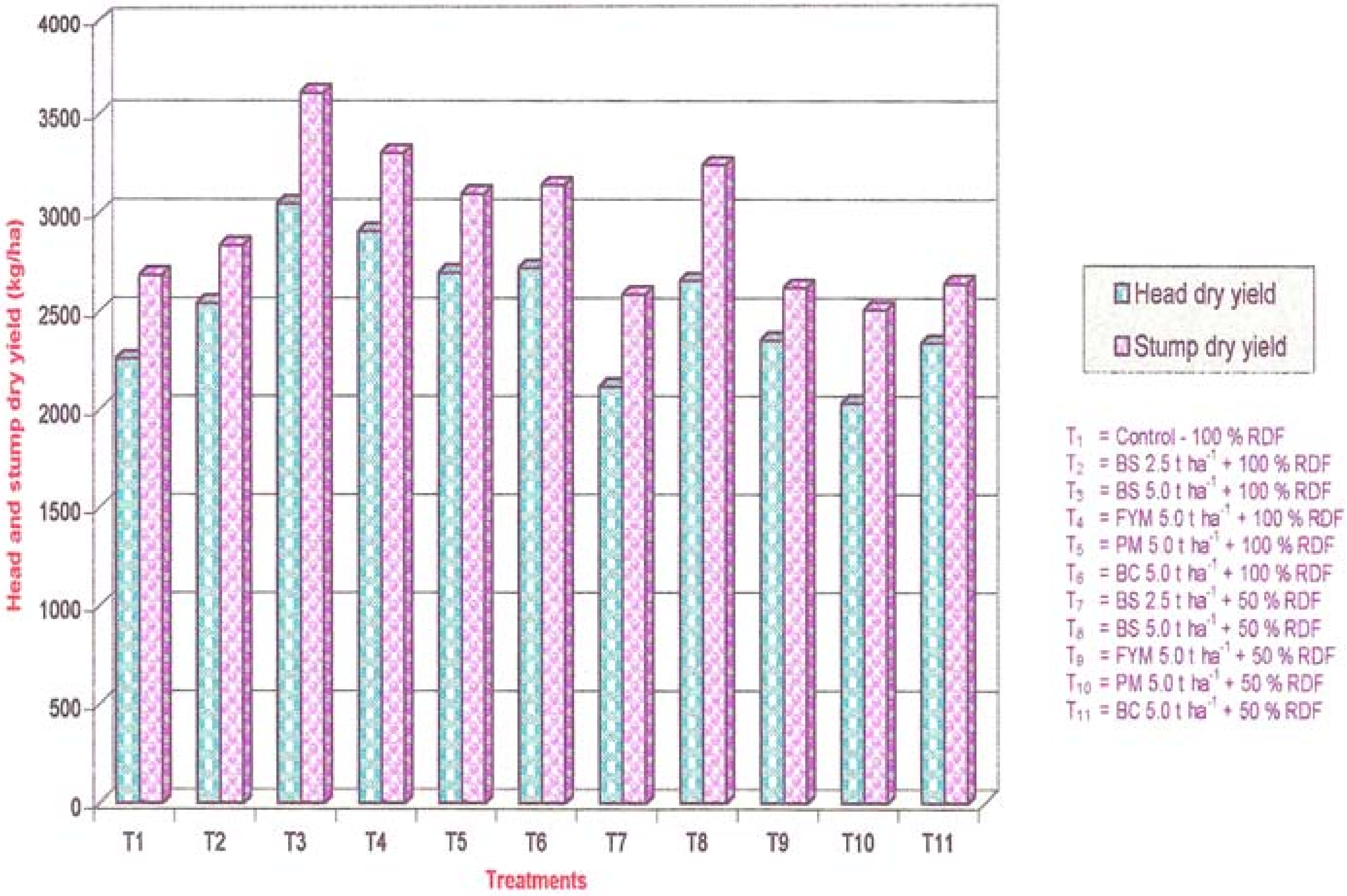


Fig. 7 : Direct effect of different industrial solid wastes with graded RDF on dry yield of cabbage head and stump

produced at application of solid wastes (BS, PM, FYM and BC) along with 50 per cent RDF. Thus, it indicates that application of solid wastes to the crop economizes half doses of N, P and K fertilizer. The supply of nutrients, conducive physical environment leading to better aeration, root activity and nutrient absorption and the consequent complementary effect would have resulted in higher cabbage head and stump yield. Increase in yield of crops due to use of different industrial waste was earlier reported by many workers (Sawarkar and Dikshit,1990 in maize and soybean with oxalic acid waste, Kumar and Mishra, 1991 in rice with pressmud, Sarkunan *et al.*, 1993 in rice with Ferochrome slag, Raman *et al.*, 1996 in sorghum with pressmud, flyash and gypsum, Kausal *et al.*, 1996 in soybean with oxalic acid waste, Tiwari *et al.*, 1998 in sugarcane with pressmud and Selvakumari *et al.*, 2000 in rice with fly ash). Saving of fertilizer dose by using the pressmud in rice nursery has been reported by Anon. (1994). Similarly Dang and Verma (1996) reported that application of SMPC and CPMC @ 10 t ha^{-1} to rice crop was equivalent to 50 and 28 per cent RDF, respectively. Gowda *et al.* (1992) indicated saving of 50 per cent RDF by incorporation of municipal solid waste in bajra crop.

5.2.1.2 Nutrient content and uptake

The N, P and K contents in head and stump were increased under the solid wastes treatments (Fig. 8 and 9). The nitrogen content both in head and stump was maximum with biological sludge and biocompost treatments, whereas, content of K was higher at biocompost treatments. Though all the materials with 100 per cent fertilizer doses increased the contents of major nutrients over control.

The removal of N by head and stump was higher under solid waste treatments. The uptake recorded with BS, FYM, PM and BC conjunction with 100 per cent RDF was increased by 41.49 and 38.58, 29.60 and 30.05, 20.98 and

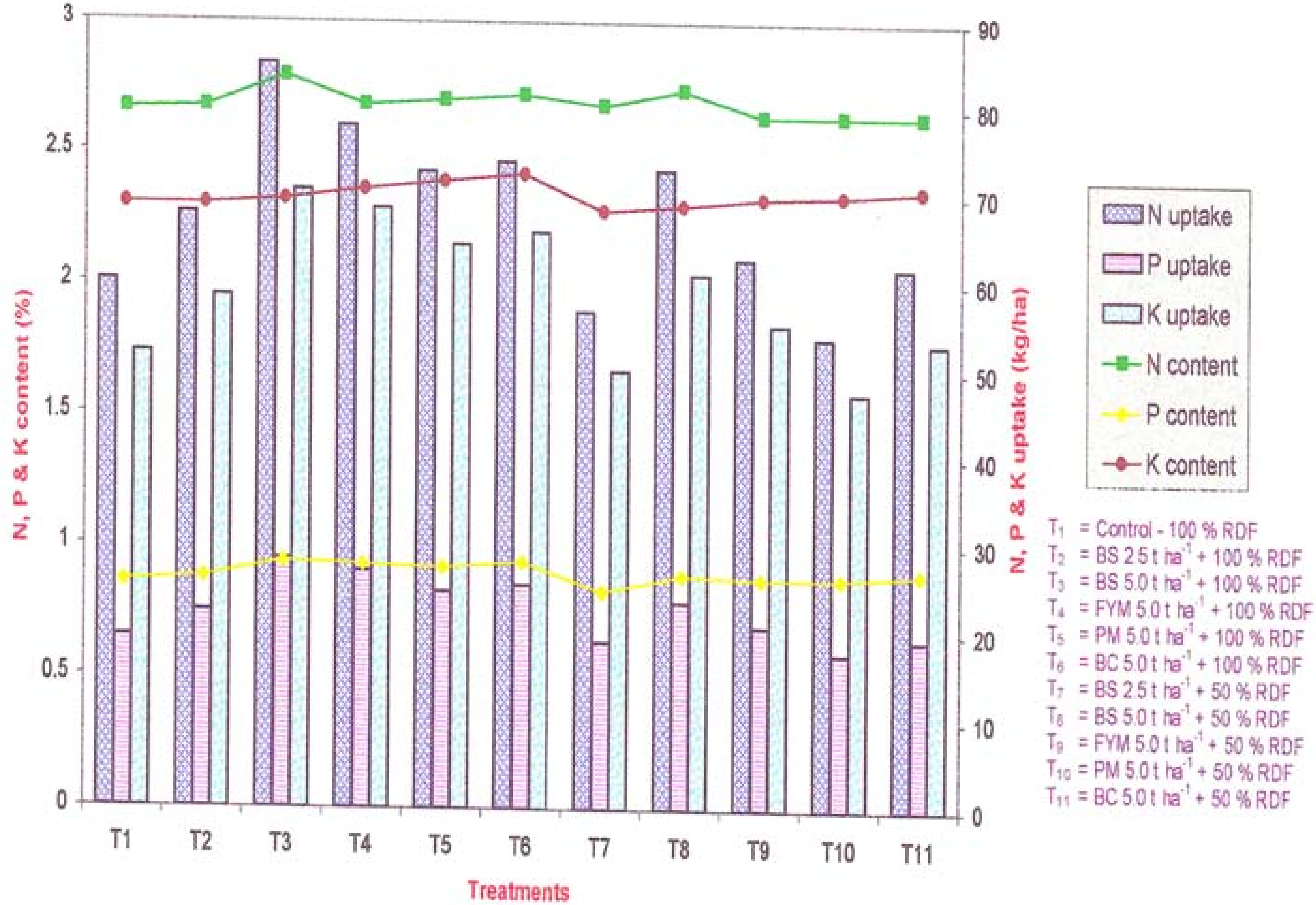
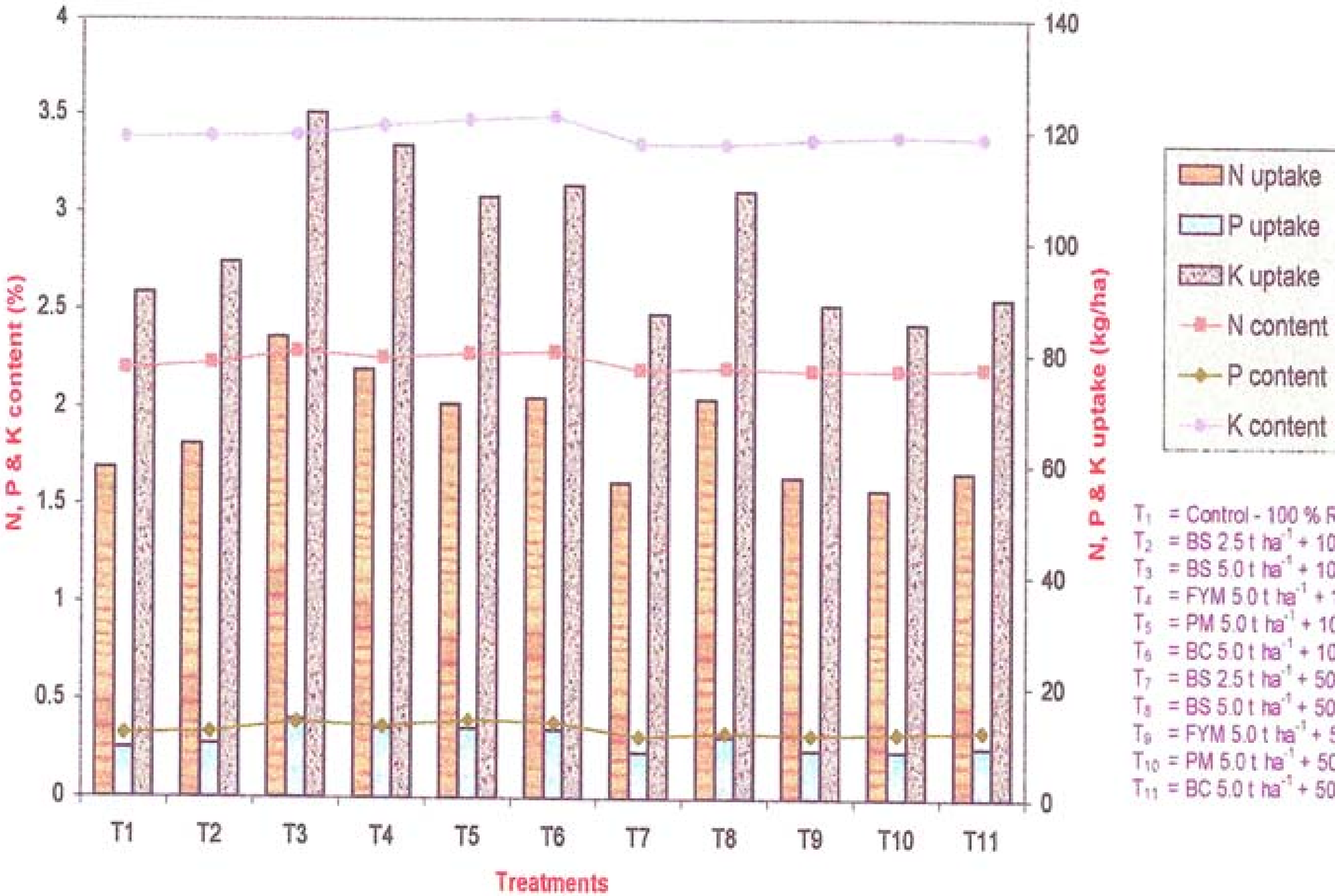


Fig. 8 : Direct effect of different industrial solid wastes with graded RDF on content and uptake of major nutrients by cabbage head



T_1 = Control - 100 % RDF
T_2 = BS 2.5 t ha^{-1} + 100 % RDF
T_3 = BS 5.0 t ha^{-1} + 100 % RDF
T_4 = FYM 5.0 t ha^{-1} + 100 % RDF
T_5 = PM 5.0 t ha^{-1} + 100 % RDF
T_6 = BC 5.0 t ha^{-1} + 100 % RDF
T_7 = BS 2.5 t ha^{-1} + 50 % RDF
T_8 = BS 5.0 t ha^{-1} + 50 % RDF
T_9 = FYM 5.0 t ha^{-1} + 50 % RDF
T_{10} = PM 5.0 t ha^{-1} + 50 % RDF
T_{11} = BC 5.0 t ha^{-1} + 50 % RDF

Fig. 9 : Direct effect of different industrial solid wastes with graded RDF on content and uptake of major nutrients by cabbage stump

19.55 and 22.85 and 21.55 per cent of head and stump, respectively. The data depicted in figures 8 and 9 also showed that the removal of N nutrient at application of solid wastes (BS, FYM, PM, and BC) along with 50 per cent RDF was practically remained more or less similar to that of control. The uptake pattern of P and K by head and stump were also similar to that of N. The increase in N, P and K uptake might be due to the supply of these nutrients by biological sludge, FYM, pressmud and biocompost as well as by creating favorable physical condition of the soil for better root proliferation and thus, facilitating more utilization. Increase in N, P and K uptake of rice and sugerbeet due to application of pressmud was reported by Kumar and Mishra (1991) and Kapur and Kanwar (1993). Selvakumari *et al.* (2000) observed increase in N, P and K uptake by rice plant due to application of fly ash. Earlier Sawarkar and Dikshit (1990) also showed increased in P and K uptake of maize and soybean crop due to application of oxalic acid waste material.

The secondary nutrients content in cabbage head and stump was not consistent. However, their uptake by head and as well as stump was spectacular (Table 28 and 29). When biosludge @ 5 t ha^{-1} with 100 per cent RDF was applied, the increase of 13.97 and 18.08 kg ha^{-1} of Ca, 5.36 and 10.70 kg ha^{-1}of Mg and 6.68 and 9.71 Kg ha^{-1}of S by head and stump, respectively over application of fertilizer alone (control). The uptake of Ca by head and stump increased by 30.21 and 19.98 per cent at application of pressmud alongwith 100 per cent RDF over control. The corresponding figures of Ca uptake at application of biocompost alongwith 100 per cent RDF were 31.61 and 22.76 per cent. Similar trend of Mg and S removal was also observed in respective treatments of biological sludge, pressmud and biocompost in head and stump. It is seen that pattern of nutrients removal at 100 per cent RDF alone (control) and application of BS, FYM, PM and BC conjoin with 50 per cent RDF were more or less similar. This may be due to fact that these nutrients are present in the organic solid wastes in considerable quantities and hence, the addition of these would have enriched the soil and thereby, enhanced the uptake of these nutrients. This finding are in accordance with those reported by Sawarkar and Dikshit (1990) in maize and soybean crop due to use of oxalic acid waste and Selvakumari *et al.* (2000) in rice crop due to application of flyash.

Application of biosludge, FYM, pressmud and biocompost with full and half recommended doses remarkably increased the concentration of Fe both in head and stump, whereas, Cu and Mn content was not conspicuous both in head and straw (Table 30 and 31). Though Zn concentration was noteworthy only in head. It implies that concentration of micronutrient was variable according to it's content. Sarkunan *et al.* (1993) reported that slag addition decreased Fe and Mn content in both straw and grain of rice while Cu and Zn in straw decreased.

With regards to total uptake of Fe, Mn, Zn and Cu (Table 53), revealed that total Fe, Mn, Zn and Cu uptake was observed higher under the treatment of addition of BS @ 5 t ha^{-1} plus 100 per cent RDF (T_3), followed by FYM plus 100 per cent RDF treatment (T_4). Application of 100 per cent RDF in conjunction with biosludge, FYM, pressmud and biocompost each at the rate of 5 t ha^{-1} increased utilization of Fe by 182, 115, 95 and 109 g ha^{-1} (68, 43, 35, and 41 per cent), respectively over control. The corresponding utilization of Mn increased by 57, 35, 27 and 32 g ha^{-1} (53, 33, 25 and 30 per cent), respectively over control.

While in case of Zn and Cu these values was increased by 58 and 15 (71 and 53 per cent), 38 and 10 (46 and 36 per cent), 25 and 4 (30 and 14 per cent) and 33 and 6 (40 and 21 per cent) g ha^{-1} under T_3, T_4, T_5 and T_6 treatments, respectively over control. It is also interesting to see that removal of micro nutrients under the treatments of addition of 50 per cent RDF alongwith

Table 53. Direct effect of different industrial solid wastes with graded fertilizer levels on total micronutrient uptake by cabbage

Treatments	Total uptake (g ha^{-1})			
	Fe	Mn	Zn	Cu
T_1= control - 100 % RDF	267	107	82	28
T_2=BS 2.5 t/ha + 100 %RDF	328	126	105	32
T_3= BS 5 t/ha + 100 %RDF	449	164	140	43
T_4=FYM 5 t/ha + 100 %RDF	382	142	120	38
T_5=PM 5 t/ha + 100 %RDF	362	134	107	32
T_6=BC 5 t/ha + 100 %RDF	376	139	115	34
T_7= BS 2.5 t/ha + 50 % RDF	286	101	84	28
T_8=BS 5 t/ha + 50 % RDF	382	135	111	36
T_9=FYM 5 t/ha + 50 % RDF	305	114	91	29
T_{10}=PM 5 t/ha + 50 % RDF	284	106	85	25
T_{11}=BS 5t/ha + 50 % RDF	317	113	94	32

incorporation of biosludge, FYM, pressmud and biocompost (each @ 5 t ha^{-1}) was more as compared to control treatment. This could be primarily be ascribed to the high content of these micronutrient in waste materials which enhanced the crop growth and hence uptake. The above results are in conformity to those reported by Sarkunan *et al.* (1993).

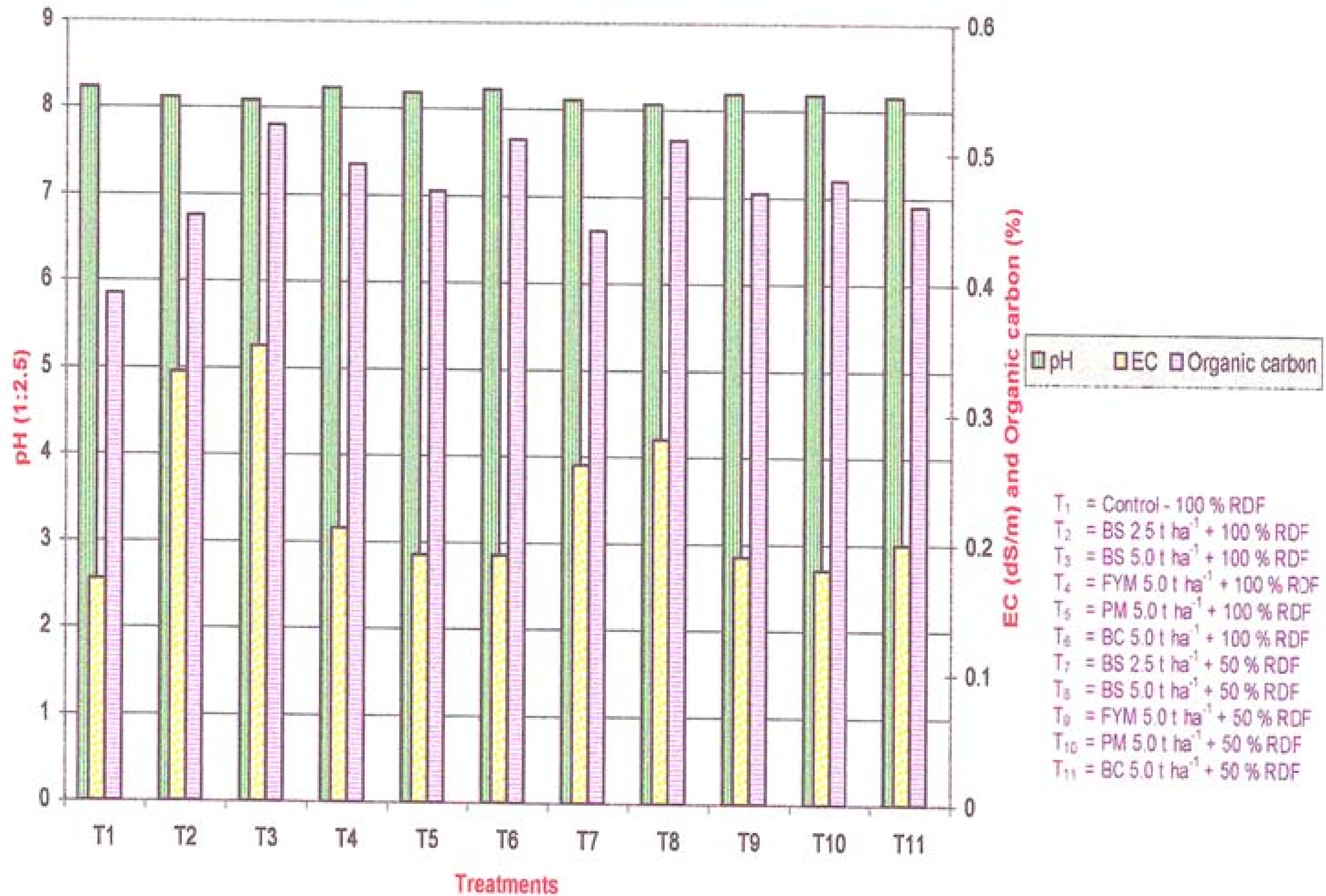
5.2.1.3 Heavy metal content

The data reported in table 32 showed that heavy metal concentration such as Ni, Pb, Cd and Co in cabbage head and stump was conspicuous due to different materials and fertilizer doses. This could be attributed to the low concentration of heavy metal in the used materials and the poor translocation of heavy metals within plant from root to the above ground portion. Ortiz Hermandez *et al.* (1999) observed that no toxicity of heavy metals was found in maize due to application of sludge for two years. Sanders (1987) confirmed that no phytotoxic effects of Ni on crop yields were measured at the maximum concentration of 77 mg Ni kg^{-1}. Carlton Smith and Stark (1987) showed that very little Pb was taken up by ryegrass and concentration in plant tissue independent of the levels in soil. Similarly Vigerust and Selmer Olsen (1986) confirmed that there was no crop uptake of Pb from sludge treated soils. Koeppe (1981) reported that Pb had no toxic effects on plants due to low bioavailability and because any absorbed Pb is immobilized in the roots. Carlton Smith (1987) concluded that concentration of Cd in crop tissue approximated to a simple linear function of the total concentration of Cd in soil.

5.2.1.4 Soil changes

5.2.1.4.1 Physico-chemical properties of soil

Application of different solid wastes alongwith 100 and 50 per cent RDF did not affect the soil reaction value. However, electrical conductivity of the soil was spectacular (Figure 10). The initial electrical conductivity value of the soil was 0.15 dSm^{-1}. The soil salinity value after application of biological sludge was



T_1 = Control - 100 % RDF
T_2 = BS 2.5 t ha^{-1} + 100 % RDF
T_3 = BS 5.0 t ha^{-1} + 100 % RDF
T_4 = FYM 5.0 t ha^{-1} + 100 % RDF
T_5 = PM 5.0 t ha^{-1} + 100 % RDF
T_6 = BC 5.0 t ha^{-1} + 100 % RDF
T_7 = BS 2.5 t ha^{-1} + 50 % RDF
T_8 = BS 5.0 t ha^{-1} + 50 % RDF
T_9 = FYM 5.0 t ha^{-1} + 50 % RDF
T_{10} = PM 5.0 t ha^{-1} + 50 % RDF
T_{11} = BC 5.0 t ha^{-1} + 50 % RDF

Fig. 10 : Direct effect of different industrial solid wastes and graded RDF on physico-chemical characteristics of the soil

only increased as compared to other treatments. This may be attributed to the higher amount of salt present in sludge. This finding are corroborated with the findings of Raman *et al.* (1996) due to application of gypsum, Mohamed and Awad (1998) due to application of straw pulp sludge and Silvakumari *et al.* (2000) due to application of fly ash.

The organic carbon status of the soil after harvest of cabbage crop, according to statistical analysis was not conspicuous. However, it increased from 0.39 at control to 0.52 per cent due to application of biological sludge in conjunction with 100 per cent RDF. Moreover, the increases in organic carbon status at FYM, PM and BC alongwith full dose of fertilizer were 25.64, 20.51 and 30.77 per cent, respectively over control. This may be due to the fact that initial material applied to the soil contained higher amount of organic matter. Positive effect of different industrial waste addition, on organic carbon status of the soil was reported by Raman *et al.* (1996) and Dang and Verma (1996) due to application of pressmud while Mohamed and Awad (1998); Fierro *et al.* (2000) and Shrikanth *et al.* (2000) due to application of straw pulp sludge, papermill sludge and industrial enriched compost, respectively.

5.2.1.4.2 Available major nutrients

The addition of different solid wastes with 100 per cent graded fertilizer levels produced marked variation in it over control (Fig. 11). The maximum was recorded at application of biological sludge in concomitant with 100 per cent RDF, followed by FYM application alongwith 100 per cent RDF. It is also seen that availability of N was same as obtained at control and that recorded at 50 per cent RDF alongwith application of solid wastes (BS, FYM, PM and BC). This increase was due to addition of inorganic materials, which contained this nutrient. This findings are congruous with those reported by Chithra *et al.* (1998) due to addition of organic wastes, Mohamed and Awad (1998) due to

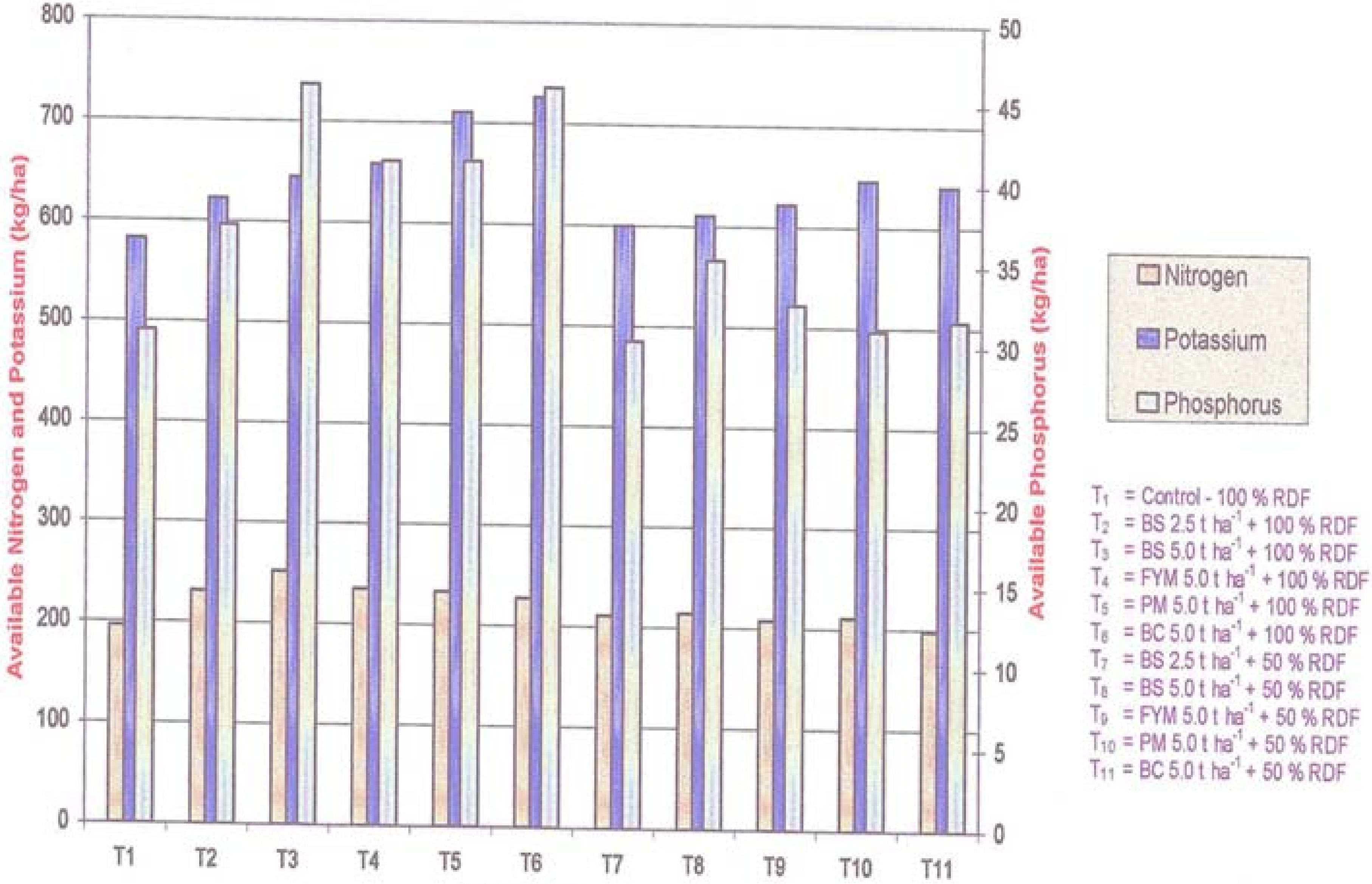


Fig. 11 : Direct effect of different industrial solid wastes and graded RDF on available nutrient status of the soil

application of straw pulp sludge and Shrikanth *et al.* (2000) due to incorporation of industrial enriched compost.

The available P_2O_5 was remarkably increased by the application of all the industrial waste materials in conjunction with 100 per cent RDF. The increase was 15.38, 10.66, 10.68 and 15.29 P_2O_5 kg ha^{-1} due to addition of BS, FYM, PM and BC each of 5 t ha^{-1}, respectively over control. The available P_2O_5 at the treatments effect of addition of all the waste material alongwith 50 per cent RDF and control was practically remained same. Increase in available P_2O_5 due to addition of waste materials can be attributed it to the P content of these waste. Dang and Verma (1996) and Selvakumari *et al.* (2000) reported similar increase in available P_2O_5 content of soil. Shrikanth *et al.* (2000) also observed increase in available P_2O_5 status of soil due to addition of enriched industrial composts.

Application of all the waste materials along with 100 per cent RDF increased the available K_2O status of soil. The maximum was recorded at biocompost application followed by pressmud treatments. Besides, all the waste materials along with 50 per cent RDF was equal to that of control treatment in respect of available K_2O status of the soil. The results are in conformity with those earlier reported by Nagarajan *et al.* (1986) and Dang and Verma (1996). Recently the results reported by Selvakumari *et al.* (2000) and Shrikanth *et al.* (2000) are also in harmony.

5.2.1.4.3 DTPA extractable micronutrients

The micro nutrient status of the soil after harvest of crop was increased remarkably due to application of different solid wastes alongwith 100 and 50 per cent fertilizer application (Table 35). The Fe content of soil at application of biological sludge @ 5 t ha^{-1} along with 100 per cent and 50 per cent RDF was 12.86 and 12.71 mg kg^{-1}, respectively. These values increased by 36.95 and 35.35 per cent over control. The corresponding value at the same level of fertilizer for Mn, Zn and Cu were increased by 40.43 and 47.95, 72.34 and 46.80 and 27.55 and 17.33 per cent, respectively over control. Similarly all the micro nutrient were also more or less increased over control treatments by the application of pressmud, FYM and biocompost treatments at 100 and 50 per cent recommended dose of fertilizer treatments. This could be attributed to addition of these nutrients by application of different solid organic wastes. Dang and Verma (1996) reported similar increase in soil micronutrient due to addition of pressmud. Mohandas and Appavu (2000) also reported the similar results due to addition of basic slag. Ortiz Hermandez *et al.* (1999) was congruous with this result.

5.2.1.4.3 DTPA extractable heavy metals

The four heavy metals determined in present study indicated that there was no remarkable increase in the heavy metal concentration in the soil (Table 36). The analysis of post-harvest soil, evidenced only a slight and non-significant increase in the heavy metal content. Besides these values were found within the permissible limits. The low concentration of heavy metals in the organic solid wastes used and also the mobility / leaching of heavy metals to the sub surface layer might be the reason for the non significant increase in heavy metal content of soil, Selvakumari *et al.* (2000) and Chitdeshwari *et al.* (1998) obtained the similar results even after the continuous addition of fly lash for three seasons. Mc Grath and Cegarra (1992) determined poor movement of Pb in soluble and exchangeable fraction of soil. However, Aldridge and Alloway (1993) warned against complacency about Pb in sludge amended soil.

5.2.2 Residual effect on summer groundnut crop

To ascertain the residual effect of different industrial organic waste, second field experiment was conducted on the same field of first experiment. The summer groundnut crop was grown as test crop.

5.2.2.1 Dry matter yield

Residual effect of solid organic wastes on pod yield indicated that incorporation of different solid waste was not conspicuous. However, the application of biological sludge @ 5 t ha^{-1} with 100 per cent fertilizer doses recorded the highest groundnut pod yield (2986 kg ha^{-1}), which was increased by 23.90 per cent over control (Fig. 12). These results are also substantiated by the number of mature pod $plant^{-1}$at various treatments (Table 37). It seems that residual waste increased the pod yield of groundnut but could not reach the significant level. Conversely, the haulm yield recorded at different treatments was spectacular (Fig. 12). The maximum haulm yield (9340 kg ha^{-1}) was recorded at application of pressmud alongwith 100 per cent recommended dose, followed by BS plus 100 per cent RDF (T_3). The haulm yield recorded with application of FYM and biocompost conjoin with 100 per cent RDF were 8990 and 8898 kg ha^{-1}. These values increased by 34.78 and 34.40 per cent over control (6670 kg ha^{-1}). It is also interesting to note that haulm yield produced with different solid wastes along with even 50 per cent RDF was significantly more or equal to yield produced at control. This indicates that most of the residual nutrients present in the soil are removed by early growth stages of crop, consequently, vegetative growth of groundnut was faster in early growth stages. This may be one of the reasons for higher haulm yield. The non-significant increase in pod yield of groundnut might be due to the higher haulm yield and previous exhaustive cabbage crop responsible for higher nutrient removal. Kumar and Mishra (1991) early reported increase in yield of maize due to

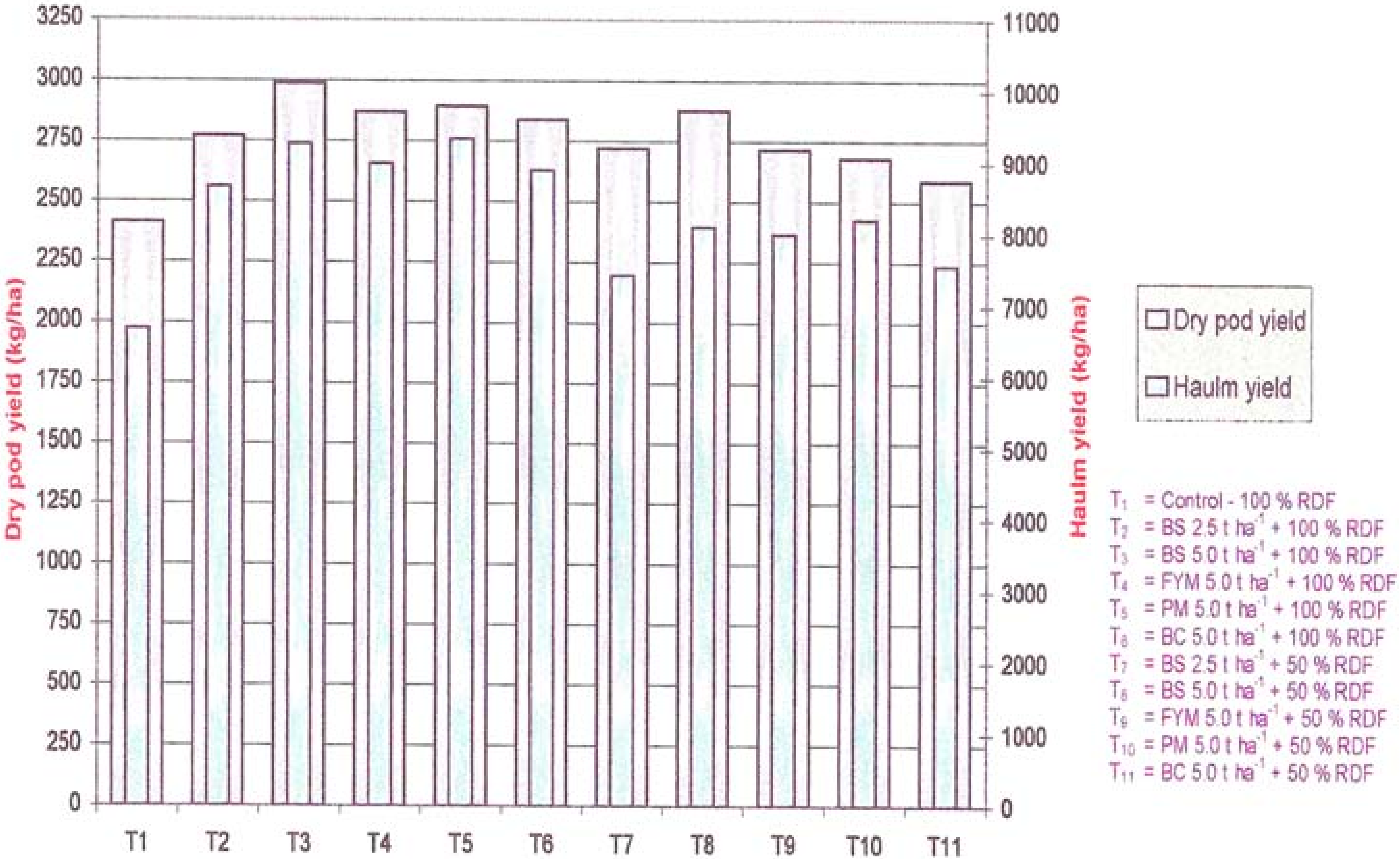


Fig. 12 : Residual effect of different industrial solid wastes on dry pod and haulm yield of summer groundnut

residual effect of pressmud. The results are also in accordance with the results reported by Dang and Verma (1996) and Mohandas and Appavu (2000).

5.2.2.2 Nutrient content and uptake

The content of major nutrients (N, P and K) in groundnut pod and haulm was not conspicuous due to treatments (Table 38 and 39). However, the uptake of these nutrients by pod and haulm was identical due to different treatments except, uptake of N by pod. The Pattern of N uptake by haulm followed the similar trend as that of haulm yield. The total maximum N uptake (200 kg ha^{-1}) was recorded with application of biosludge alongwith 100 per cent RDF which was closely followed by pressmud application alongwith 100 per cent RDF (Table 54). The removal of N at FYM plus 100 per cent RDF and BC plus 100 per cent RDF was 189 and 191 kg ha^{-1} , respectively. Besides, removal of N with BS, FYM, PM and BC application with 50 per cent RDF recorded an increase of 45, 35, 37 and 28 kg N ha^{-1} over control. The root growth conducive physical environment created on account of solid organic wastes to the soil would have facilitated better N absorption.

Regarding P uptake, the results showed (Table 54) that the integration of solid wastes either with the 100 or 50 per cent RDF recorded remarkable increase in P uptake. Application of bio-sludge @ 5 t ha^{-1} with 100 and 50 per cent RDF recorded an increase of 7.23 and 3.67 kg ha^{-1} (44 and 23 per cent) over application of fertilizer alone. The corresponding increase in P at FYM, pressmud and biocompost with 100 and 50 per cent RDF application were 4.25 and 1.15 (26 and 8 per cent), 6.65 and 2.36 (41 and 15 per cent) and 6.40 and 1.39(40 and 9 per cent) kg ha^{-1} over control. With respect to K uptake (Table 54), the biosludge addition @ 5 t ha^{-1} alongwith 100 and 50 per cent RDF increased the uptake to the tune of 38 and 20 kg ha^{-1} (42 and 22 per cent) over control. When FYM plus 100 and 50 per cent fertilizer were applied the increase

Table 54 Residual effect of different industrial solid wastes on total major nutrient uptake by groundnut

Treatment	Total uptake (kg ha^{-1})		
	N	P	K
T_1=control - 100 % RDF	134	16.15	91
T_2=BS 2.5 t/ha + 100 % RDF	179	19.76	117
T_3= BS 5 t/ha + 100 % RDF	200	23.28	129
T_4= FYM 5 t/ha + 100 % RDF	189	20.40	124
T_5= PM 5 t/ha + 100 % RDF	195	22.8	131
T_6=BC 5 t/ha + 100 % RDF	191	22.55	128
T_7=BS 2.5 t/ha + 100 % RDF	161	16.69	101
T_8= BS 5 t/ha + 100 % RDF	179	19.82	111
T_9= FYM 5 t/ha + 100 % RDF	169	17.40	109
T_{10}=PM 5 t/ha + 100 % RDF	171	18.51	112
T_{11}=BC 5 t/ha + 100 % RDF	162	17.54	106

was 33 and 18 kg ha^{-1} (36 and 20 per cent) over control. Similarly when pressmud and biocompost @ 5 t ha^{-1} plus 100 and 50 per cent fertilizer were applied the increase was 40 and 21 (44 and 23 per cent) and 37 and 15 (41 and 16 per cent) kg ha^{-1} , respectively over addition of fertilizer alone. The significant increase in P and K uptake might be due to the supply of these nutrients by different organic waste materials as well as by creating favorable physical condition of the soil. Kumar and Mishra (1991) observed increased N, P and K uptake by maize crop due to the application of pressmud to the soil.

The secondary nutrients total uptake (Table 55) showed that application of biosludge plus 100 and 50 per cent RDF (T_3 and T_8) increased uptake of 22 and 12 kg ha^{-1} of Ca, 17 and 10 Kg ha^{-1} of Mg and 10 and 5 kg ha^{-1} of S over control. When FYM was applied @ 5 t ha^{-1}along with 100 and 50 per cent fertilizer (T_4 and T_9), the increase was 18 and 11 kg ha^{-1} of Ca, 14 and 8 kg ha^{-1} of Mg and 7 and 4 kg ha^{-1} of S over control. Similarly when pressmud and biocompost were applied along with 100 and 50 per cent fertilizer, the uptake of Ca, Mg and S was also increased in the same pattern as that of recorded in the FYM application. These nutrients are present in considerable quantities in the above organic wastes and hence the addition of these would have enriched the soil with them and thereby enhanced the uptake of Ca, Mg and S nutrients.

The concentration of Fe, Mn. Zn and Cu in pod was found to be non-significant due to various treatments (Table 42). Though the concentration of Fe, Mn and Zn in haulm was of indicative (Table 43). Significantly higher concentration of Fe, Mn and Zn were observed under addition of BS @ 5 t ha^{-1} in conjunction with 100 per cent RDF followed by T_6, T_5 and T_4 treatments. In general the concentration of Fe, Mn and Zn was recorded higher under the treatments of incorporation of solid wastes (Biosludge, FYM, pressmud and biocompost) over control.

Table 55. Residual effect of different industrial solid wastes on total secondary nutrient uptake by groundnut

Treatment	Total uptake (kg ha^{-1})		
	N	P	K
T_1=control - 100 % RDF	39	35	15
T_2=BS 2.5 t/ha + 100 % RDF	51	46	20
T_3= BS 5 t/ha + 100 % RDF	61	53	25
T_4= FYM 5 t/ha + 100 % RDF	57	49	22
T_5= PM 5 t/ha + 100 % RDF	60	51	24
T_6=BC 5 t/ha + 100 % RDF	58	49	23
T_7=BS 2.5 t/ha + 100 % RDF	43	40	18
T_8= BS 5 t/ha + 100 % RDF	51	45	20
T_9= FYM 5 t/ha + 100 % RDF	50	43	19
T_{10}=PM 5 t/ha + 100 % RDF	50	43	20
T_{11}=BC 5 t/ha + 100 % RDF	48	41	19

The removal of Fe, Mn, Zn and Cu by groundnut pod was not noteworthy. In contrast, utilization of these nutrients by haulm was conspicuous due to different treatments (Table 42 and 43). For assessing the treatment differences with respect to nutrient removal, total uptake of all micronutrient was worked out and reported in table 56. The total removal of Fe, Mn, Zn and Cu under the treatment T_3 (Biosludge @ 5 t ha^{-1} plus 100 per cent RDF) was increased by 47.16, 55.34, 66.25 and 66.67 per cent, respectively over control. Similarly total removal of Fe, Mn, Zn and Cu under the treatment T_4 (FYM plus 100 per cent RDF) increased by 35.62, 41.19, 51.25 and 55.57 per cent, respectively over control. Like wise, corresponding increases of Fe, Mn, Zn and Cu under the treatment T_5 (PM plus 100 per cent RDF) and T_6 (Biocompost plus 100 per cent RDF) were 41.14 and 41.05,46.30 and 43.84, 60.63 and 52.50 and 63.36 and 57.58 per cent, respectively over fertilizer application alone (control). It seems also that utilization of Fe, Mn Zn and Cu were observed higher under application of biosludge, FYM pressmud and biocompost (5 t ha^{-1}) in conjunction with even 50 per cent RDF. It indicates that addition of carbonaceous material not only provide the major nutrients but also supplies the micro nutrients to residual crop which is reflected in growth and yield, consequently their uptake.

5.2.2.3 Heavy metal content

Like the cabbage crop, the concentration of Ni, Pb, Cd and Co in groundnut pod and haulm were also not indicative due to different treatments (Table 44), as groundnut crop was taken after cabbage in residual soil fertility . The data presented in table revealed that concentration of Ni, Pb, Cd and Co was slightly higher under haulm as compared to pod.

Table 56. Residual effect of different industrial solid wastes with graded fertilizer levels on total micronutrient uptake by groundnut

Treatment	Total uptake (g ha^{-1})			
	Fe	Mn	Zn	Cu
T_1=control - 100 % RDF	1162	365	160	99
T_2=BS 2.5 t/ha + 100 % RDF	1495	471	218	146
T_3= BS 5 t/ha + 100 % RDF	1710	567	266	165
T_4= FYM 5 t/ha + 100 % RDF	1576	518	242	155
T_5= PM 5 t/ha + 100 % RDF	1540	534	257	162
T_6=BC 5 t/ha + 100 % RDF	1639	525	244	156
T_7=BS 2.5 t/ha + 100 % RDF	1306	442	207	124
T_8= BS 5 t/ha + 100 % RDF	1518	505	231	143
T_9= FYM 5 t/ha + 100 % RDF	1460	465	222	138
T_{10}=PM 5 t/ha + 100 % RDF	1465	468	215	135
T_{11}=BC 5 t/ha + 100 % RDF	1362	453	216	134

5.2.2.4 Soil changes

5.2.2.4.1 Physico-chemical properties

The soil reaction value was not affected due to different treatments (fig. 13). Soil salinity value was slightly increased due to organic waste application. Because of these wastes contained higher amount of salt, which reflected in increased electrical conductivity of soil. The organic carbon status of the soil was not maintained in significant amount. However, the organic carbon contents in the treatments of application of solid organic wastes recorded higher amount of organic matter content of the soil. It has been seen that organic waste addition treatments (T_2 to T_{11}) with 100 and 50 per cent recommended doses of fertilizer increased the organic carbon status of the soil by 25 to 44 per cent over the control. Webber (1978) earlier reported the increase in organic carbon status of soil due to addition of sewage sludge. Kumar and Mishra (1991) and Yaduvanshi and Yadav (1996) also reported similar results due to use of pressmud.

5.2.2.4.2 Available major nutrients

Availability of all the major nutrients was higher under the treatments of addition of solid organic wastes along with 100 and 50 per cent recommended doses of fertilizer over the control treatments (Fig. 14). When the biological sludge @ 5 t ha^{-1} plus 100 per cent RDF was applied, the increase was 48, 12.45 and 71 kg ha^{-1} N, P_2O_5 and K_2O, respectively over addition of fertilizer alone. Slightly more or less similar increase was also recorded due to addition of FYM, pressmud and biocompost alongwith 100 per cent RDF. Besides, addition of these organic wastes even at 50 per cent RDF was also recorded similar higher available major nutrients as compared to only addition of chemical fertilizer alone. The results are in accordance with those reported by Yaduvanshi and Yadav (1996) and Shrikanth *et al.* (2000).

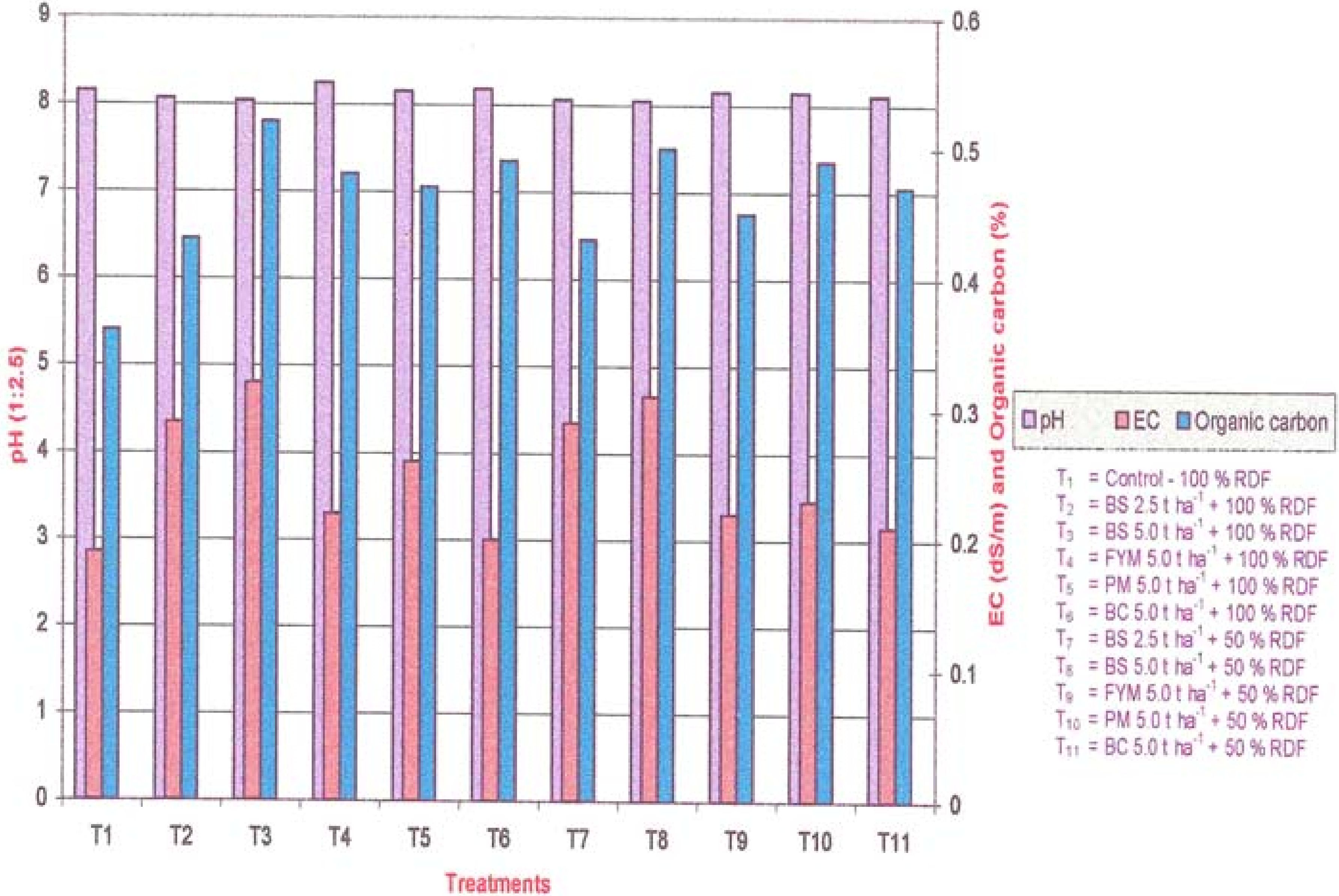
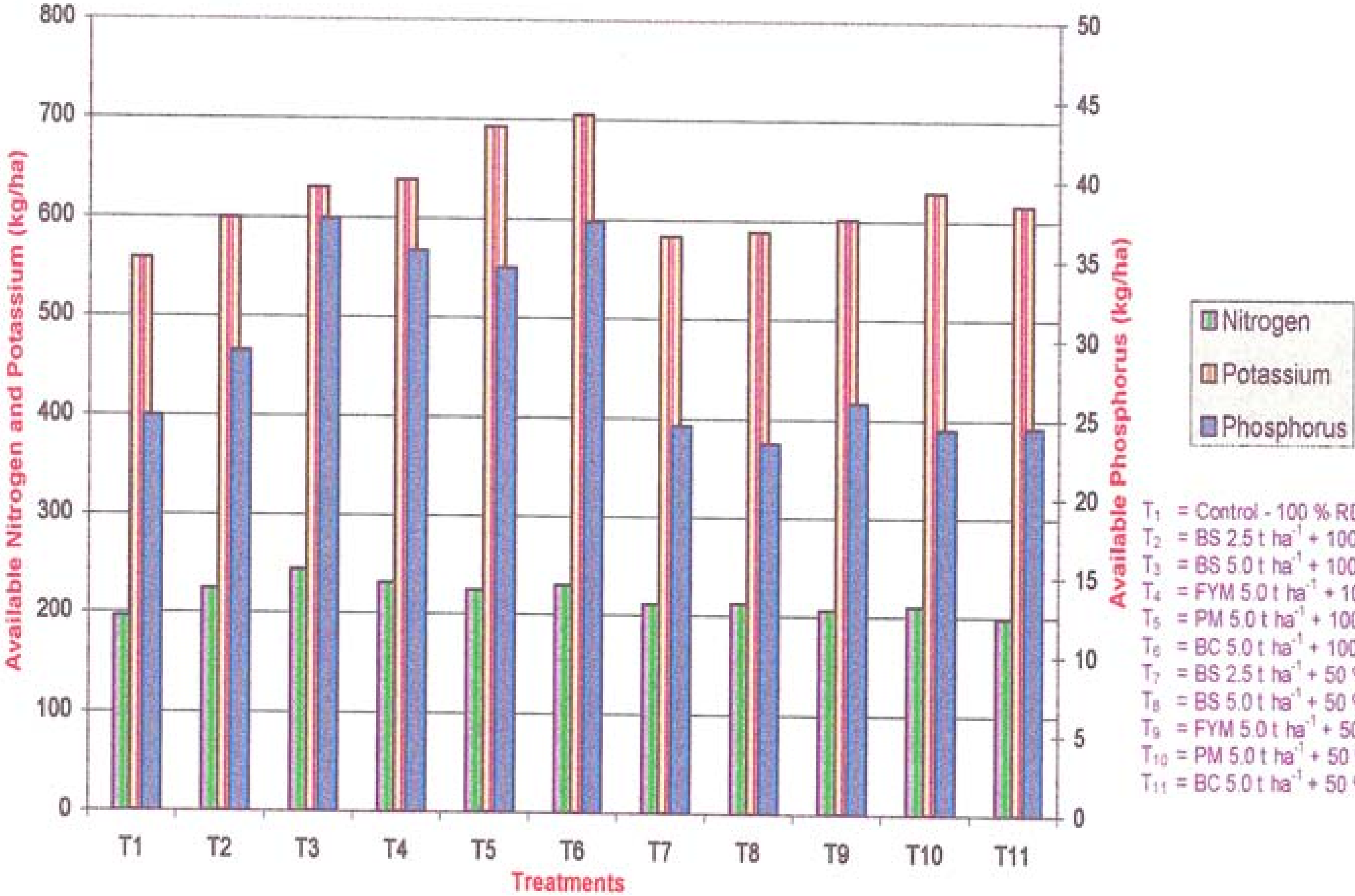


Fig. 13 : Residual effect of different industrial solid wastes with graded RDF on physico-chemical characteristics of the soil



T_1 = Control - 100 % RDF
T_2 = BS 2.5 t ha^{-1} + 100 % RDF
T_3 = BS 5.0 t ha^{-1} + 100 % RDF
T_4 = FYM 5.0 t ha^{-1} + 100 % RDF
T_5 = PM 5.0 t ha^{-1} + 100 % RDF
T_6 = BC 5.0 t ha^{-1} + 100 % RDF
T_7 = BS 2.5 t ha^{-1} + 50 % RDF
T_8 = BS 5.0 t ha^{-1} + 50 % RDF
T_9 = FYM 5.0 t ha^{-1} + 50 % RDF
T_{10} = PM 5.0 t ha^{-1} + 50 % RDF
T_{11} = BC 5.0 t ha^{-1} + 50 % RDF

Fig. 14 : Residual effect of different industrial solid wastes with graded RDF on available major nutrients of the soil

5.2.2.4.3 DTPA extractable micro nutrients

Among the Fe, Mn, Zn and Cu micronutrient status of the soil, only Fe and Zn were found spectacular (Table 47). The initial value of Fe had 9.33 mg kg^{-1} which increase to 11.88, 10.84, 11.04 and 11.66 mg kg^{-1} at biosludge (T_3), FYM(T_4), pressmud (T_5) and biocompost (T_6) alongwith 100 per cent recommended doses of fertilizer. It is also seen that marginal decrease in Fe by 0.35 mg kg^{-1} from initial value to control treatments. It is also observed that all the solid organic waste application even 50 per cent RDF was accumulated more Fe as compared to only addition of fertilizer alone. Similar improvement in Zn status of the soil was also observed. This may be due to the fact that addition of organically waste not only provide the major nutrients but also provides the micronutrient, which is necessary for plant growth. The results are in corroborates with the results of Yaduvanshi and Yadav (1996).

5.2.2.4.4 DTPA extractable heavy metal

Ni, Cd, Pb and Co determined in present investigation indicated only slightly and non-significant increases in the heavy metal concentration (Table 48). Ni and Pb ranged from 0.78 and 0.79 mg kg^{-1} at control to 0.93 and 0.93 mg kg^{-1} at application of biosludge alongwith 100 per cent RDF while, Cd and Co varied from 0.07 and 0.89 mg kg^{-1} at control to 0.073 and 0.97 mg kg^{-1} at application of biocompost alongwith 100 per cent RDF. All the values indicated that there were marginal increases from initial status of the soil. The DTPA extractable contents of heavy metals viz., Ni, Pb, Cd and Co were found within the permissible limits.

5.2.2.4.5 Physical properties of soil

The data presented in table 49 showed that the effect of the different treatments of industrial wastes on the bulk density and water stable aggregate (> 0.25 mm) in soil was found to be non-indicative. However, reduction in the bulk density was observed in the treatments that received solid wastes along with full and half N, P and K, than in the treatment that received N, P and K alone. The bulk density of soil ranged between 1.50 Mg m^{-3} in control and 1.43 Mg m^{-3} in biosludge @ 5 t ha^{-1} plus 100 per cent RDF (T_3).

It has been observed that application of biosludge, FYM, pressmud and biocompost with full and half RDF enhanced the water stable aggregate in the soil as compared to control (Table 49). The per cent aggregate (> 0.25 mm) varied from 74.46 at control to 78.10 per cent at biocompost @ 5 t ha^{-1} plus 50 per cent RDF (T_8). Improvement in bulk density and water stable aggregate indicate the improvement in soil properties. The improvement in per cent aggregate due to use of wastes was also reported by Sewaram *et al.* (1992); Shinde *et al.* (1995) and Raman *et al.* (1996).

SUMMARY AND CONCLUSION

VI SUMMARY AND CONCLUSION

The present investigation was carried out on Typic Chromuster soil of Navsari in two phases. In the first phase, two pot experiments were carried out involving use of two diluted effluents irrigation (RIL and UPL) in combination with each of 100, 75, 50 and 0 per cent recommended doses of NPK fertilizers and one control (100 per cent RDF irrigated with canal water). Treatments were imposed in completely randomized design (CRD) for ascertaining direct effect on onion crop as well as cumulative effect on fodder maize in the same pot. In the second phase, two field experiments were conducted. Wherein, the relative performance of different industrial solid waste such as biological sludge @ 2.5 and 5 t ha^{-1}, pressmud, biocompost and FYM each of 5 t ha^{-1} alongwith full and half doses of NPK fertilizer and one control (100 per cent recommended dose of fertilizer) was evaluated on cabbage crop (direct effect) and summer groundnut crop (residual effect) with four replications in randomized block design (RBD). The results of the present study are summarized below.

6.1 Effect of effluent water

6.1.1 Direct effect on onion crop

6.1.1.1 Use of diluted RIL and UPL effluent water alongwith 100 per cent RDF (320 and 285 g pot^{-1}) as a source of irrigation water increased fresh yield of onion bulb by 33.47 and 18.87 per cent over canal water irrigation in conjunction with 100 per cent RDF (239.75 g pot^{-1}).

6.1.1.2 6.1.1.2 Yield of bulb and leaves was statistically same at 100 per cent recommended dose with normal water and 50 per cent recommended dose with RIL and UPL effluent waters.

6.1.1.3 The content and uptake of major nutrients (N, P and K) by onion bulb and leaves were recorded significantly higher under both the effluent water irrigation treatments as compared to canal water irrigation. The uptake of N, P and K by onion with RIL effluent irrigation and UPL effluent irrigation in conjunction with 100 per cent RDF increased by approximately 1.5 fold over canal water irrigation alongwith 100 per cent recommended dose of fertilizer.

6.1.1.4 Uptake of secondary nutrients such as Ca, Mg in bulb was not affected by effluent irrigation. However, Ca and Mg concentration in leaves were significantly increased. The removal of Ca, Mg and S by bulb and leaves were significantly increased under effluent irrigation as compared to canal water irrigation.

6.1.1.5 Concentration of Fe, Mn, Zn and Cu in bulb and leaves recorded with RIL and UPL effluent water alongwith 50, 75 and 100 per cent recommended doses were significantly higher as compared to treatment of normal water plus 100 per cent recommended dose. Utilization of Fe, Mn, Zn and Cu by onion with RIL effluent plus 100 per cent RDF got increased by 58, 106, 102 and 60 per cent, respectively over canal water irrigation alongwith 100 per cent RDF. Similarly the corresponding utilization of such nutrients at U+100 treatment got increased by 33, 62, 51 and 46 per cent, respectively.

6.1.1.6 Concentration of heavy metals such as Pb, Cd, Ni and Co in plant tissue was below the phytotoxicity limits.

6.1.1.7 Effluent irrigation decreased the soil pH, increased the electrical conductivity and improved the organic carbon status of the soil as compared to canal water irrigation.

6.1.1.8 Available N status after RIL effluent irrigation increased 2 to 3 fold, while marginal increase was noted after UPL effluent irrigation. Increase of available P was noted more after RIL effluent irrigation as compared to UPL effluent irrigation. The reverse was true in case of available K of the soil.

6.1.1.9 At the same level of fertilizer dose (100 per cent recommend dose), the DTPA extractable micronutrients with RIL effluents increased the Fe, Mn, and Zn content by 31, 34 and 28 per cent, respectively and that with UPL effluent increased Fe, Mn, Zn by 24, 80 and 20 per cent, respectively over canal water irrigation alongwith 100 per cent RDF. The concentration of Cu after RIL and UPL effluent irrigation got marginally increased.

6.1.1.10 The concentration of heavy metal in soil was below the critical limit. Ni and Co was significantly affected where as Cd and Pb statistically remained same.

6.1.2 Cumulative effect on fodder maize

6.1.2.1 Fresh and dry matter of fodder maize produced at RIL effluent plus 50 per cent RDF (675.50 and 95.34 g pot $^{-1}$) and UPL effluents plus 50 per cent RDF (606.50 and 87.94 g pot^{-1}) were statistically same as that obtained at 100 per cent RDF and irrigated with canal water (589 and 85.41 g pot $^{-1}$).

6.1.2.2 Fresh yield of fodder maize with RIL and UPL effluent irrigation alongwith 100 per cent RDF got increased by 29 and 21 per cent, respectively over canal water irrigation alongwith 100 per cent RDF.

6.1.2.3 The content of N, P and K in fodder maize with RIL and UPL effluents irrigation alongwith 100 per cent RDF was significantly higher as compared to canal water irrigation in conjunction with 100 per cent RDF. Like wise, removal of N, P and K was 1.5 fold higher under effluent water irrigation as compared to canal water irrigation.

6.1.2.4 Content of secondary nutrient such as Ca and S was significantly increased whereas, Mg content in fodder maize was not affected. At the same level of fertilizer dose (100 per cent RDF), the utilization of Ca, Mg and S by fodder maize with RIL effluent was increased by 44, 40 and 60 per cent, respectively over canal water irrigation. Such increase of Ca, Mg and S under UPL effluent irrigation was noted 28, 38 and 75 per cent.

6.1.2.5 Concentration of Fe, Mn, Zn and Cu in fodder maize were significantly higher under RIL and UPL effluent irrigation as compared to canal water irrigation. The utilization of Fe, Mn, Zn and Cu were recorded higher under RIL effluent irrigation as compared to UPL effluent and normal water irrigation, though UPL effluent irrigation removed more Fe, Mn, Zn and Cu nutrients as compared to canal water irrigation.

6.1.2.6 Concentration of heavy metals such as Pb, Cd, Ni and Co in fodder maize did not increase remarkably and remained below critical limits of phytotoxicity.

6.1.2.7 Both the effluent water irrigation (RIL and UPL) decreased the soil reaction value, increased the salinity and improved the organic carbon status of the soil as compared to canal water irrigation.

6.1.2.8 Available N status after RIL effluent irrigation was increased approximately by 3 fold whereas, such increment under UPL effluent water irrigation was about 31 per cent over canal water irrigation. At the same level of fertilizer (100 per cent RDF), the RIL and UPL effluent increased the available P status by 114 and

49 per cent over canal water irrigation. Improvement of available K was more under UPL effluent as compared to RIL effluent.

6.1.2.9 DTPA extractable micronutrients in soil were significantly higher under effluents irrigation as compared to normal water irrigation. On an average, Fe increased by two fold, Mn increased by 1.5 to 2 fold and Zn and Cu were slightly increased after RIL and UPL effluent irrigation.

6.1.2.10 The concentration of DTPA extractable heavy metals in soil such as Ni, Pb, Cd and Co were remained below the critical toxicity limit.

6.2 Effect of solid wastes

6.2.1 Direct effect on cabbage crop

6.2.1.1 Among the different solid wastes, application of biological sludge @ 5 t ha^{-1} in conjunction with 100 per cent RDF produced significantly higher cabbage head and stump yield, followed by FYM biocompost and pressmud in decreasing order. The application of BS (T_3), FYM (T_4), PM (T_5) and BC (T_6) alongwith full recommended dose produced 34.89, 28.60, 19.37 and 20.43 per cent higher dry matter head yield respectively, over control.

6.2.1.2 The cabbage fresh and dry matter yield obtained with half recommended dose alongwith application of BS, PM, FYM and BC were statistically at par with control.

6.2.1.3 The N, P and K content in cabbage head and stump were significantly higher under solid waste application treatments as compared to control. The uptake of N recorded with BS, FYM, PM and BC in conjunction with 100 per cent RDF was increased by 41.49 and 38.58, 29.60 and 30.05, 20.98 and 19.55 and 22.85 and

21.55 per cent of head and stump, respectively. The uptake pattern of P and K by head and stump was also similar to that of N.

6.2.1.4 The secondary nutrient like Ca, Mg and S content in head and stump were not significantly affected due to different treatments. However, removal of these nutrients was affected. Ca, Mg and S uptake by cabbage head and stump was higher with application of biosludge @ 5 t ha^{-1} in conjunction with 100 per cent RDF followed by FYM @ 5 t ha^{-1} plus 100 per cent RDF. The treatment effect of application of solid wastes (BS, FYM, PM and BC) alongwith 50 per cent RDF remained statistically same with the treatment effect of control.

6.2.1.5 Concentration of Fe and Zn was significantly higher in cabbage head whereas, that of Mn and Cu was not affected due to different solid waste treatments and in cabbage stump, only Fe concentration was significantly increased under solid waste treatments. Application of 100 per cent RDF in conjunction with BS (T_3), FYM (T_4), PM (T_5) and BC (T_6) increased utilization of Fe by 68, 43, 35 and 41 per cent over control. The corresponding utilization of Mn increased by 53, 33, 25 and 30 per cent, respectively over control, while in case of Zn and Cu these values were increased by 71 and 53, 46 and 36, 30 and 14 and 40 and 21 per cent, respectively over control.

6.2.1.6 Concentration of heavy metals such as Ni, Pb, Cd and Co in cabbage head and stump remained unaffected and below the phytotoxicity limit.

6.2.1.7 Application of different solid wastes alongwith 100 and 50 per cent RDF did not affect the soil reaction value. However, electrical conductivity value after application of biological sludge was only increased as compared to other treatment. The organic carbon status of the soil after harvest of cabbage crop was not affected significantly. However, it increased from 0.39 at control to 0.52per cent due to application of biological sludge in conjunction with RDF. Application of FYM, PM and BC alongwith full dose of fertilizer increased the organic carbon status by 25, 21 and 31 per cent, respectively.

6.2.1.8 The highest available N in soil after harvest of cabbage was recorded at application of BS alongwith 100 per cent RDF (251 kg ha^{-1}), followed by FYM addition in conjunction with 100 per cent RDF (235 kg ha^{-1}). The P_2O_5 increase was 15.38, 10.66, 10.68 and 15.29 kg ha^{-1} due to addition of BS, FYM, PM and BC, respectively over control. The maximum K_2O was recorded at biocompost application followed by pressmud treatments. Besides, all the waste materials alongwith 50 per cent RDF were comparable to that of control treatment in respect of available N, P_2O_5 and K status of the soil.

6.2.1.9 DTPA extractable micronutrient status after harvest of crop was increased remarkably due to application of different solid wastes alongwith full and half recommended fertilizer. The Fe content of soil with addition of BS @ 5 t ha^{-1} alongwith full and half RDF got increased by 40 and 35 per cent, over control. The corresponding increase at the same level of fertilizer for Mn, Zn and Cu were 40 and 48, 72 and 47 and 28 and 17 per cent, respectively over control. Similarly all the micronutrients were also more or less increased over control treatments by the application of PM, FYM and BC treatments with full and half recommended dose of fertilizer treatments.

6.2.1.10 The four heavy metals determined in the present study (Ni, Pb, Cd and Co) indicated that there was no remarkable increase in the heavy metal concentration in the soil. Besides, theses values were found within the permissible limits.

6.2.2 Residual effect on summer groundnut

6.2.2.1 Residual effect of solid wastes on pod yield was not conspicuous. However, application of BS @ 5 t ha^{-1} with 100 per cent fertilizer dose recorded the highest groundnut pod yield (2986 kg ha^{-1}) which was increased by 23.90 per cent over control.

6.2.2.2 The haulm yield recorded at different treatments was spectacular. The maximum haulm yield (9340 kg ha^{-1}) was recorded at application of pressmud alongwith full recommended dose of fertilizer, followed by BS plus 100 per cent RDF. The haulm yield recorded with application of FYM and BC and 100 per cent RDF were increased by 35 and 34 per cent over control (6670 kg ha^{-1}). Besides, haulm yield produced with different solid wastes alongwith even 50 per cent RDF was significantly more or equal to yield produced at control.

6.2.2.3 The content of major nutrients (N, P and K) in groundnut pod and haulm was not affected due to different treatments. However, the uptake of these nutrients by pod and haulm was identical. The total N uptake (200 kg ha^{-1}) was recorded with application of BS alongwith 100 per cent RDF followed by PM alongwith 100 per cent RDF. Integrated use of solid wastes either with 100 or 50 per cent RDF recorded remarkable increase in P uptake. Application of

BS @ 5 t ha^{-1} with 100 and 50 per cent RDF increased the P uptake by 44 and 23 per cent over application of fertilizer alone. Addition of solid wastes also increased the K uptake by groundnut at both the levels i.e. 100 and 50 per cent RDF over control.

6.2.2.4 Total uptake of the secondary nutrients (Ca, Mg and S) showed that application of organic solid wastes alongwith 100 per cent RDF increased uptake approximately by 18 to 22 kg ha^{-1} of Ca 8 to 14 kg ha^{-1} of Mg and 7 to 10 kg of S over control.

6.2.2.5 The concentration of Fe, Mn and Zn in haulm was recorded higher under the treatments of incorporation of solid wastes (BS, FYM, PM and BC) over control. The removal of Fe, Mn Zn and Cu by groundnut pod was not affected. However, utilization of these nutrients by haulm was conspicuous due to different treatments. The total removal of Fe, Mn, Zn and Cu under the treatment (BS @ 5 t ha^{-1} plus 100 per cent RDF) was increased by 47, 55, 66 and 67 per cent respectively over control. Similarly, higher total removal of these micronutrients was also noted under the treatment of FYM, pressmud and biocompost.

6.2.2.5 The concentration of Ni, Pb, Cd and Co in groundnut pod and haulm was not significantly affected due to different treatments. The concentration of Ni, Pb, Cd and Co was noted slightly higher under haulm as compared to pod.

6.2.2.7 After harvest of residual groundnut soil reaction value remained unaffected, soil salinity value slightly increased due to organic waste application. The organic carbon status of the soil was not statistically affected. However, the organic carbon content in the treatments of application of solid organic wastes recorded higher amount of organic matter content of the soil.

6.2.2.8 Availability of all the major nutrients (N, P and K) was higher under treatments of addition of solid organic wastes alongwith 100 and 50 per cent recommended dose of fertilizer over the control. The BS @ 5 t ha^{-1} plus 100 per cent RDF increased, the available N, P_2O_5 and K_2O by 25, 50 and 13 per cent, respectively over addition of fertilizer alone. More or less similar increase was also recorded due to addition of FYM, PM and BC alongwith 100 per cent RDF.

6.2.2.9 All the solid organic waste application with 100 and 50 per cent RDF accumulated more Fe and Zn as compared to only addition of fertilizer alone.

6.2.2.10 Ni, Cd, Pb and Co concentration in soil indicated slightly and non-significant increases from initial status of the soil and content of these heavy metals were found within the permissible limits.

6.2.2.11 The effect of the different treatments of industrial wastes on the bulk density and water stable aggregates (> 0.25 mm) in soil was found to be non-indicative. However, reduction in bulk density and improvement in water stable aggregate was found with addition of organic waste material treatments.

CONCLUSION

In the pot culture experiment wherein the possibility of fertilizer reduction at optimum effluent dilution was tried with onion (Direct effect) and fodder maize crop (Cumulative effect), there was clear cut indication that in both the studies about 50 per cent fertilizers can be saved. Use of diluted effluent water improved the fertilizer use efficiency and available nutrient status in soil.

The results of the field experiments indicated that application of industrial solid wastes could save the half recommended doses of fertilizers in direct effect on cabbage. The residual effect on pod yield of groundnut was non significant though, haulm yield showed remarkable increase. In both the effect (Direct and residual) the utilization of nutrient increased to a considerable extent and available nutrient status in the soil was also improved.

The study clearly indicates that the disposal of industrial wastes viz., liquid and solid can be made for better crop production and sustaining soil fertility. However, more such studies should be undertaken in future.

Future line of research

1. Experiments involving use of industrial waste should be conducted on long term basis for sound recommendation.
2. The regular monitoring should also be done for development of salinity and build up of heavy metals in soils put under constant industrial effluent / waste use.

REFERENCES

REFERENCES

Abdou, F.M. and Nennah, M. (1980). Effect of irrigating loamy sand soil by liquid sewage sludge and its content of some micronutrient. *Pl. Soil,* **56** : 53-57.

Abubacker, M.N. and Rao, G.R. (1995). Effect of pressmud on rice. *J. Indian Soc. Soil Sci.*, **43** (2) : 300-302.

Achari, M.S., Dhakshinamoorthy, M. and Arunachalam, G. (1999). Studies on the influence of paper mill effluents on yield, availability and uptake of nutrients in rice. *J. Indian. Soc. Soil Sci.,* **47** (2) : 276-280.

*Adarkatti, I.B. and Rao, G.S.G. (1980). Proc. Seminar on disposal of Sugar-mill and distillery effluent by U.P. Government Pollution Board at Lucknow on 24th April, 1980.

Ahmad, S and Evans, H. (1960). Cobalt : a micronutrient element for the growth of soybean plant under symbiotic conditions. *Soil Sci.*, **90** : 205

Ajmal, M. and Khan, A.U. (1983). Effect of sugar factory effluent on soil and crop plants. *Environ. Pollut.*, **30** : 135-141.

Ajmal, M., Khan, M.A. and Nomani, A.A. (1984). Effect of industrial dairy processing effluent on soil and crop plants. *Environ. Pollut.,* **33** : 97-106.

Ajmal, M. and Khan, A.U. (1984a). Effect of brewery effluent on agricultural soil and crop plants. *Environ. Pollut.*, **33** : 341-351.

Ajmal, M. and Khan, A.U. (1984b). Effect of vegetable ghee manufacturing effluent on soil and crop plants. *Environ. Pollut.*, **34** : 367-379.

Aldridge, K. and Alloway, B.J. (1993). Lead in soils and food crops. *A literature review for food science*, Divison 1, Ministry of Agriculture, Fisheries and Food. Queen Marry and West field College, University of London.

Alloway, B.J. (1990). Heavy metals in soils, Blackie and Sons Ltd (Publ)., U.K.

Anonymous (1989). Use of spent wash in agriculture. *Ann. Res. Report,* Regional Sugarcane Research Station, G.A.U., Navsari. p, 39-46.

Anonymous (1994). Nursery management in rice. Annual Report, National Agricultural Research Project, G.A.U., Navsari.

Bahirat, D.W., Nisal, B.V. and Pakkala, V.R. (1989). Utilization of urea factory effluent for irrigation purposes. *Ferti. News,* **34** (3) : 31-39.

Bajpai, P.D. and Dua, S.P. (1972). Studies on the utility of distillery effluent for its' manurial value and it's effect on soil properties. *Indian. Sug.,* **21**: 687-690.

Bansal, R.L., Nayyar, V.K. and Takkar, P.N. (1992). Accumulation and bioavailability of Zn, Cu, Mn, and Fe on soil polluted with industrial waste water. *J. Indian Soc. Soil Sci.,* **40** (4) : 796-799.

Bhagavati, A.U. and Durai, R.N. (1996). Utilization of coir pith as manure for rice and potassium use efficiency. *J. Indian Soc. Soil Sci.,* **44** (3) : 445-447.

*Bocko, J. (1980). Improvement of light soils irrigated with sewage effluents as a result of organic matter accumulation. *Roczniki Gleboznewze,* **31** (3) : 149-154. (Fide-*Irrig, and Drain. Abstr.,* **8** (1) : 17, 1982).

Binodkumar, N.K., Prasad, Roy, H.K. and Sarkab, A.K. (2000). Influence of cobalt on forage production and micronutrient content in lucerne. *J. Indian Soc. Soil Sci.,* **48** (2) : 411-413

Cambell, R W., Miller, J.H., Reynolds, J.H. and Schreeg, T.M. (1983). Alfalfa, sweetcorn and wheat response to long-term application of municipal waste water to crop land. *J. Environ. Qual.,* **12** : 243-249.

Carlton Smith, C.H. (1987). Diatry intake of Cd arising from the utilization of sludge in agriculture. In : *Smith, S.R. (eds, 1996) Agricultural recycling of sewage sludge and the environment.* Published by CAB International Walling ford, Oxon. U.K.

*Carlton Smith, C.H. and Stark, J.H. (1987). Sites with a history of sludge deposition. *Interim report of field trials.* April 1983-March 1986. WRc Report No. DoE 1376 WRc Medmenham, Marlow

Chapman, H.D. (1965). Cation exchange capacity. In : *Black, C.A.(Ed), Method of soil analysis part II,* American Society of Agronomy, Inc. Maidson, p. 984-898.

Chaudhari, S.K., Jha, A.N. and Srivastava, D.K. (1987). Effect of paper mill effluent on seed germination and seedling growth of maize. *Environ. Eco.*, **5** : 285-287.

Chitdeshwari, T., Baskar, A. and Saravanan, A. (1998). National seminar on development on soil science. *Abstract.* **16-19** : 239

Chithra, L., Jakaki, P. and Velu, V. (1998). Impact of organic waste on the nitrogen availability in rice soil of Thambirabarani river tract. *Madras Agric. J.*, **85** (10-12) : 683-685.

Dang, Y.P. and Verma, K.S. (1996). Direct and residual effect of pressmud cakes in rice-wheat cropping system. *J. Indian Soc. Soil Sci.*, **44** (3) : 448-450.

Datta, S.P., Biswas, D.R., Shararan, N., Ghosh, S.K. and Rattan, R.K. (2000). Effect of long term application of sewage effluents on organic carbon, bioavailable phosphorus, potassium and heavy metal status of soil and contents of heavy metals in crops grown there on. *J. Indian Soc. Soil Sci.*, **48** (4) : 836-839.

Day, A.D., Stroehlein, J.L. and Tucker, T.C. (1976) Effect of treated plant effluent on soil properties. *J.Wat Pollut..Cont. Fed.*, **44** (3) : 372-375.

Devarajan, L. and Oblisami, G. (1995). Effect of distillery effluent on soil properties, yield and quality of sugar cane. *Madras Agric. J.,* **82** (5) : 397-399.

Dewis, J. and Freitas, F. (1984). Physical and chemical methods of soil and water analysis. *FAO Soils Bulletin-10.* Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi. p. 33-35.

*Dmitrieva, V., Matulyavichene, N.I. and Melnikova, A.I. (1979). Irrigation of perennial herbage species with washings from dairy complexes. *Korma,* **5** : 26-27 (Fide-*Irrig. and Drain. Abstr.*, **7** (2) : 82, 1981).

Emmiamath, V.S. and Rangaswami, G. (1971). Studies on the effect of heavy doses of nitrogeneous fertilizer on the soil and rhizosphere microflora of rice. *Mysore J. Agric. Sci.,* **5** : 39-58.

*Escolar, R.P. (1966). Stability of aggregates treated with distillery slops or black strap molasses. *J. Agric. Univ. P. Rico.,* **50** : 174-185 (Fide – *Soils and Ferti. Abstr.*, **30** (1) : 78, 1967).

Fazeli, M.S., Sathyanarayan, S., Satish, P.N. and Lata, M. (1991). Effect of Paper mill effluents on accumulation of heavy metals in coconut trees. *Environ-Geo and Wat. Sci.,* **17** (1) : 47-50 (Fide – *Soils and Ferti. Abstr.*, **54** (8) : 1281, 1991).

Feigin, A., Bielorai, H., Day, K.T and Giskin, M. (1978). The nitrogen factor in the management of effluent irrigated soils. *Soil Sci.,* **125** : 248-254.

Fierro, A., Angers, D.A. and Beavchamp, C.J. (1999). Application of paper mill sludge along with N and P fertilizer on soil physical properties. *Soil Sci. Soc. Am. J.,* **4** : 1013-1018.

*Fillery, I.R.P and Vlek, P.L. (1986).Reappraisal of the significance of ammnia volatization as an N loss mechanism in flooded rice field *Ferti. Res.*, **9** : 79-88.

*Gautam, D.D. and Bishnoi, S.C. (1990). Studies on the effects of urmul dairy effluents on soil characteristics and growth of wheat plant. *Adv. Pl. Sci.,* **3** (2) : 236-24., (Fide-*soils and Ferti. Abstr.,* **54** (12) : 1924, 1991).

Gladis, R. Subhas Chandra Bose, M and Fazlullghkhan, A.K. (1999). Waste water irrigation and N and P fertilization on HCN and NO_3 content of fodder sorghum. *Madras Agric. J.,* **86** (4-6) : 250-255.

Gomez, A.K. and Gomez, A.A. (1984). Statistical procedure for agricultural research, II edition, John Willey and Sons, New York.

*Gonzales, M.V. and Tinaco, A.P. (1982). Effect of volume and time of application of distillery slops on the growth and yield of sugarcane. *Proc. 29th Ann. Conv. Phillipines Sugar Techno. Ass.* p. 467-490.

Gowda, T.K.S., Radhakrishna, D, Balakrishna, A.N., Sreenivas, K.N. (1992). Studies on the manurial value and nutrient enrichment of municipal waste compost produced from banglore city garbage. *Proc. Nat. seminar organic farming* MPKV, Pune. p. *39-47.*

Gupta, V.K (1994). 25 years of micronutrient research in soils and crops of Haryana. *Dept. Soil Sci., H.A.U., Hissar.* p. 99

Hani, H., Siegenthaley, A. and Candinas, T. (1996). Soil effects due to sewage sludge application in agriculture. *Ferti. Res.,* **43** (1-3) : 149-156.

Intraweck, A., Store, L.R., Ellis, R.J. and Whitney, D.A. (1982). Influence of fertilizer source on soil physical and chemical properties. *Soil. Sci. Soc. Am. J.,* **46** : 832-836.

Jackson, M.L. (1973). Soil chemical analysis. *Prentice Hall of India Pvt. Ltd. New Delhi.*

Jadhav, H.D. (1973). Effect of spent wash (distillery waste) on the properties of non-calcarious medium black soil. *M.Sc. (Agri). Thesis submitted to the M.P.A.U., Rahuri.*

*Jensen, F. (1981a). Application of dairy waste water to agriculture crops on sandy soils. *Tidsskrift for planteanl*, **85** (2) : 159-170 (Fide:- *Irrig. and Drain Abstr.*, **11** (1) : 14, 1985).

*Jensen, F (1981b). Application of potato process water to agricultural crops on sandy soils. *Tidsskrift for planteanl*, **85** (1) : 47-85 (Fide : *Irrig. and Drain. Abstr.*, **11** (1) : 14, 1985).

*Jayaraman, S. (1988). Studies on different nitrogen levels on forage yield of bajra hybrid under sewage irrigation. *Livestock Advisor,* **13** (12) : 3-4 (Fide – *soils and Ferti. Abstr.*, **54** (8) : 1255, 1991).

Juvarkar, A.S., Shende, A., Jhawale, P. R., Satyanarayana, S., Deshbratar, P. B., Bal, A. S. and Juvarkar, A. (1992). Biological and induatrial wastes as a source of plant nutrients. In : *Fertilizers, organic manures, recyclable wastes and biofertilizers* (Ed. H L S Tandon) FDCO, New Delhi. pp. 72-90.

Kamalam, N. and Raj, D. (1980). Effect of tannery effluents on germination and nutrient uptake of ragi. *Madras Agric. J.,* **67** : 441-444.

*Kannan, K. and Oblisami, G. (1990). Influence of irrigation with pulp and papermill effluent on soil chemical and microbial properties. *Biol. and fertility of soils.,* **10** (3) : 197-201 (Fide – *soils and ferti. Abstr.*, **54** (5) : 615, 1991).

*Kansal, B.D. and Singh, J. (1983). Influence of the municipal waste water and soil properties on the accumulation of heavy metals in plants. *Heavy metals in the Environ.,* **1** : 413-416 (Fide-*Irrig. and Drain. Abstr.*, **11** (2) : 79, 1985).

Kapur, M.L. and Kanwar, R.S. (1993). Influence of agro industrial wastes on yield and nutrient uptake by sugar-beet. *J. Indian Soc. Soil. Sci.,* **41** (3) : 572-573.

Kaushal, A., Rapat, A.K., Verma, L.N. and Khare, A.K. (1996). Industrial wastes as a carrier for rhizobium and its effect on soyabean. *J. Indian Soc. Soil Sci.,* **44** (2) : 249-252.

Kaswala, R.R.and Despande, S.B. (1983). Physico-chemical and minerological characteristics of some coastal and Indian soil series of south Gujarat-I. *J. Indian Soc. Soil Sci.,* **31** : 281-286.

*Khatri, S. and Jamajum, K. (1988). The effect of treated waste water on the concentration of nutrients and some heavy metals in plants and soils. *Dirasat,* **15** (11) : 29 (Fide – *Irrig and Drain Abstr.*, **17** (1) : 16, 1991).

King, L.D. (1982). Land application of untreated industrial waste water. *J. Environ. Qual.,* **11** : 638-644.

Koeppe, D.E. (1981). Lead : understanding the minimal toxicity of lead in plants. In : *Effect of heavy metal pollution on plants* (ed. Leep, N.W.). Applied Science publishers London, p. 55-76.

Kuhad, M.S., Malik, R.S., Singh, R.and Singh, A. (1989). Studies on mobility and accumulation of heavy metals in agricultural soil receiving sewer water irrigation. *J. Indian Soc. Soil Sci.,* **37** : 290-294.

Kumar, V. and Mishra, B. (1991). Effect of two types of pressmud cake on growth of rice-maize and soil properties. *J. Indian Soc. Soil Sci.,* **39** (1) : 109-113.

Kumaravelu, M. and Dhakshinamoorthy, M. and Chitralekha, R. (2000). Effect of tannery effluent on soil physico-chemical properties and growth of finger millet. *Madras Agric. J.* **87** (4-6) : 253-256.

Larson, W.L., Gilley, J. and Linden, D.R. (1975). Consequences of waste disposal on land. *J. Soil Wat. Conserv.,* **30** : 68-71.

Lindsay, W.L. and Norvell, W.A. (1978). Development of DTPA micronutrient soil test for Zn, Fe, Mn and Cu. *Soil Sci. Soc. Am.. J.,* **42** : 421-408.

Mahida, U. N. (1981). Water pollution and disposal of waste water on land. Tata, Mc Graw-Hill publishing company Ltd., New Delhi. p. 82-83.

Malti, S.M. Dhakshinamurthy, M. and Arunachalam, G. (1998). Effect of paper factory effluent on soil available macro nutrients and yield of rice. *Madras. Agric. J.*, **85** (10-12) : 564-566.

Malti, S.M., Dhakshinamurthy and Arunachalam, G. (2000). Accumulation and availability of Zn, Cu, Mn and Fe in soils polluted with paper mill waste water. *Madras Agric. J.* **87** (4-6) : 237-240.

*Marecos, D. Monte, H., Silva, E., Sousa, M and Silva, N. (1989). Effects on soil and crops of irrigation with primary and secondary effluents. *Wat. Sci. Techno.*, **21** (6) : 427-434.

*Mark, C.H. (1980). Effects of metal in sludge treated soil and crops. *Technical report T.R.251,* WRc. Medmenham, Marlow.

Mayalagu, K. (1983). Influence of different snill amendments on the physical properties of a heavy black soil and yield of groundnut TMV in the periyar vaigai command area. *Madras Agric. J.*, **70** (5) : 304-308.

Mc Grath, S.P. and Cegarra, J. (1992). Chemical extractability of heavy metals during and after long term application of sewage sludge to soil. *J. Soil Sci.,* **43** : 313-321.

*Mohamed, S.A. and Awad, Y.H. (1998). Evaluation of the physical and chemical properties of soil with application of wheat strap pulp waste water sludge. *Arab Uni. J. Agric. Sci.,* **6** (2) : 605-607.

Mohandas, S. and Appavu, K. (2000). Direct and residual effect of combined application of basic slag with green leaf manure on soil available nutrients and yield of rice. *Madras Agric. J.,* **87** (1-3) : 53-56.

Mortvedt, J.J., Cox, F.R., Shuman, L. M. and Welch, R. (1991). Micronutrient in agriculture. *second edition., Soil Sci. Soc. Am., Inc.* Madison, USA.

Mukherjee, U. and Sahai, R. (1988). Effect of distillery waste on seed germination seedling establishment and early seedling growth of *Cajanus cajan . Acta Botanica India,* **16** (2) : 182-185.

Nagarajan. R., Mamickam, T.S. and Kethanaluraman, G.V. (1986). Utilization of coir pith as manure for groundnut. *Madras Agric. J.,* **73** (8) : 447-449.

Narwal, R.P., Singh, M. and Singh, J.P. (1991). Effect of Ni enriched sewage water on the accumulation of Ni and other heavy metals in corn. *J. Indian Soc. Soil. Sci.,* **39** (1) : 123-128.

Neelam and Sahai, R. (1988). Effect of fertilizer factory effluent and seed germination, seedling growth pigment content and biomass of *Sesamum indicum* Linn. *J. Environ. Biol.* **9** (1) : 45-50.

Nennah, M., Kobbla, T., Shehata, A and Gamai, I. (1982). Effect of irrigation to loamy sand soil by sewage effluents on its content of some nutrients and heavy metals. *Pl. Soil,* **65** : 289-292.

*Niedzwiecki, E., Stanwski, S., Murkowski, A. and Malinowski, R. (2000). Preliminary studies on usefulness as fertilizer of a by product in the form of ammonium sulphate and ammonium nitrate after denitrogenization of flue gases for maize cultivation. *Agricultura,* **81** : 203-209 (Fide – *soils and ferti. Abstr.* **63** (11) : 1872, 2000).

Olsen, S.R., Watanabe, C.V. and Dean, L.H. (1954). Estimation of available phosphorus in soil by sodium bicarbonate. *Cir. USDA No.939.*

*Ortiz Hermandez, M.L., Sanchez, E. Guteirper, M. (1999). Effect of the addition of residual load on an agricultural soils and maize cultivation. *Revista, International de contaminacion Ambiental.* **15** (2) : 69-77 (Fide– *soils and Ferti. Abstr.,* **63** (11) : 1873, 2000).

Palaniswami, C and Ramuia, U.S. (1994). Effect of continuous irrigation with paper factory effluent on soil properties. *J. Indian Soc. Soil Sci.,* **42** (1) : 139-140.

Pande, H.P.U., Singh, B.K. and Bhatnagar, S. (1990). Effect of tannery effluents on sugars and yield of sugarcane plants. *Bharatiya Sugar.,* **15** (7) : 57-60

Pang, P.C., Chu, C.M. and Hedlin, R.A. (1975). Effect of pH and nitrifer population on nitrification of bund applied and homogeneously mixed urea nigtrogen in soil *Can. J. Soil Sci.,* **55** : 15-21.

Patel, K.P. and Singh, B. (1991). A comparatives study on the effect of gypsum, pressmud and pyrites on lechate composition, soil properties and yield of rice and wheat on sodic soil. *J. Indian Soc. Soil Sci.,* **39** (1) : 154-159.

Pathak, H., Joshi, H.C., Chaudhari, R., Karla, N. and Dwivedi, M.K. (1998). Distillery effluent as soil amendment for wheat and rice. *J. Indian Soc. Soil Sci.,* **46** (1) : 155-157.

Patil, G.D. and Shinde, B.N. (1995). Effect of spent wash, spent slurry and pressmud composts on maize. *J. Indian Soc. Soil Sci.,* **43** (4) : 700-702.

Piper, C.S. (1956). Soil and plant analysis. *Inter Science Publ. Inc.,* New york.

*Pollard, G. (1991). Sites with a long history of sludge disposal, phase II. *Progress Report to the development of the environment; October 1990 to March 1991.* WRc. Report No. DoE 2769-M. WRc Medmenham, Marlow.

*Rajannan, G. and Oblisami, G. (1978). Effect of paper factory effluents on soil and crop plants. Paper presented in the seminar on *' Role of chemical engineers in rural development'* at Coimbatore. p.1-16.

*Rajaram, N. and Janaradhanan, K. (1988). Effect of distillery effluents on seed germination and early seedling growth of different crops. *Seed Res.,* **16** (2) : 173-177, (Fide-*Irrig. and Drain Abstr.* **17** (1): 12, 1991).

Ramaswami, P.P. (1999). Recycling of agricultural and agro-industry wastes for sustainable agricultural production. *J. Indian Soc. Soil Sci.,* **47** (4) : 661-665.

Ramchandran, V. and D'Souza, T.J. (1999). Plant uptake of Cd, Zn and Mn from soil amended with increasing level of Cd-enriched sewage sludges and city composts. *J. Indian Soc. Soil Sci.,* **47** (4) : 738-743.

Raman, S., Patel, A.M., Shah, G.B. and Kaswala, R.R. (1996). Feasibility of some industrial waste for soil improvement and crop production. *J. Indian Soc. Soil Sci.,* **44** (1) : 147-150.

Ranwa, R.S. (1999). Waste water utilization in agriculture, potentials and problem a review. *Agricultural Reviews, Karnals,* **20** (2) : 93-102.

*Rasiah, V., Voroney, R.P., Groenevelt, P.H. and Kachanoski, R.G. (1990). Modification in soil water retention and hydraulic conductivity by an oil refinery effluent. *Soil Techno.*, **3** (4) : 367-372 (Fide : *Sois and Fertil. Abstr.*, **54** (6) : 826, 1991).

*Reddy, D. T. and Raj, S.A.(1975). Cobalt nutriation of groundnut in relation to growth and yield. *Pl. Soil.* **42** : 145

Robertson, W.K., Lutrick, M.C. and Yuan, T.L. (1982). Heavy application of liquid digested sludges on three ultisols. Effect of soil chemistry. *J. Environ Qual.* **11** (2) : 278-282.

Sahai, R., Shukla, N., Jabeen, S. and Sexena, P.K. (1985). Pollution effect of distillery wastes on the growth behaviour of phaseolus radiates. *Environ. Pollut.,* **37** : 245-253.

Sanders, J.R., Mc Graph, S.P. and Adam, T. (1987). Zn, Cu and Ni concentration in soil extracts and crops grown on four soils treated with metal-loaded sewage sludge. *Environ. Pollut.,* **44** : 193-210.

Sarkunan, V., Misra, A.K. and Nayar, P.K. (1993). Effect of ferrochrome slag on the yield and nutrient content of rice on an acid soil. *J. Indian Soc. Soil Sci.*, **41** (3) : 594-595.

*Sauerbeck, D. (1982). Landw. Forsah, *sandesh.* **39** : 108

Sawarkar, N.J. and Dikshit, P.R. (1990). Use of oxalic acid industry waste as a source of sulphur. *J. Indian Soc. Soil Sci.,* **38** (2) : 333-335.

Schipper, L.A., Williamson, J.C., Kettles, H.A. and Speir, T.W. (1996). Impact of land-applied tertiory treated effluent on soil bio-chemical properties. *J. Environ. Qual.,* **25** (5) : 1073-1077.

Selvakumari, G., Basker, M., Jayarith, D. and Mathan, K.K. (2000). Effect of integration of flyash with fertilizer and organic manures on nutrient uptake of γice in Alfisol. *J. Indian Soc. Soil Sci.,* **48** (2) : 268-278.

Sewaram, Khybri, M.L., Bhardwaj P and Gupta, O.P. (1992). Effect of lime and pressmud on soil properties and crop yield on acidic soil of doon valley. *J. Indian Soc. Soil Sci.,* **40** : 613-615.

*Sweden, F.J. and Atkinson, H.J. (1951). The effect of waste sulphate liquor solids on the chemical and physical properties of soil. *Soil Sci., Serv. Dept. Agric. Ottawa,* **31**: 93-98.

*Shinde, B.N., Arote, S.B. and Patil, A.S. (1995). *Proc. D.S.T.A. 45th Ann. Conven.* Part-I : A-23.

Shrikanth, K., Srinivasamurthy, C.A., Siddaramappa, R. and Ramakrishna, V.R. (2000). Direct and residual effect of enriched composts. FYM, vermicompoist and fertilizer on properties of Alfisol. *J. Indian Soc. Soil Sci.,* **48** (3) : 496-499.

Singh, A.K. and Pandeya, S.B. (2000). Chemical pools of Cd in sludge treated soils and their contribution to rajmash (*Phaseolus Vulgaris* L.). *J. Indian Soc. Soil Sci.,* **48** (3) : 544-55.

*Singh, A. (1961). Indian J. Sugar Res. and Dev. Ud. V. part 4 (Fide-*Indian Sug.,* **21** : 687-690).

Singh, R., Singh, V.S. and Shukla, A.K. (1991). Yield and heavy metals contents of berseem as influenced by sewage water and refinery effluent. *J. Indian Soc. Soil Sci.,* **39** : 402-404.

Sivaswami, S.N. (1990). Effect of pollutants on the nutrient status of field soils. *J. Indian Soc. Soil Sci.,* **38** : 663-666.

Sivaswami, S.N. (1991). Changes due to taniliquor and tanina amendments in arable soil. *J. Indian Soc. Soil Sci.*, **39** : 78-83.

Smith, J.H. (1976). Leaching loss of nitrate nitrogen in ground water. *J. Environ. Qual.*, **5** : 113-116.

Smith, J.H. and Hayden, C.W. (1984). Nitrogen availability from potato processing waste water for growing corn. *J. Environ. Qual.*, **13** : 151-156.

Somawanshi, R.B. and Yadav, A.M. (1990). Effect of distillery effluent on soil chemical properties and composition of leachate. *D.S.T.A., Ann. Conv.*, **40** : 101-108.

*Striban, M., Deliu, C., Morar, G. and Tican, L. (1986). The influence of waste water containing nitrogen on potatoes. *Gradina Botanica,* 229-234 (Fide-*Irrig-and Drain Abstr.*, **15** (2) : 92, 1989).

*Stahl, P.D. and Williams, S.E. (1986). Oils share process water affects activity of vesicular arbuscular fungi and rhizobiuim, four years after application to soil. *Soil Biol and Biochem.*, **18** (4) : 451-455 (Fide-*Soils and Fertil., Abstr.*, **51** (5) : 447, 1988).

*Stehlik,K. (1987). Irrigation with yeast plant waste waters. *Sci. Agric. Bohemoslovacu,* **19** (1) : 21-32 (Fide-*Fld.crop Abstr.* **40** (12) : 952, 1987).

*Stewart, A.(1953). *6th International Grass Congr.* **1** : 718

*Subba Rao, B. (1972). A low costwaste treatment method for the disposal of distillery waste water. *Res. Prgamon Press*. p. 1275-1282.

Subbiah, B. V. and Asija, G. L. (1956). A rapid procedure for the estimation of the available nitrogen in the soils. *Curr. Sci.,* **25** : 259-260.

Subbiah, S. and Ramula, U.S. (1979). Influence of wastes addition on soil characteristics. *Mysore J. Agric. Sci.*, **13** : 408-418.

Tiwari, R.C., Arvindkumar and Mishra, A.K. (1996). Influence of treated sewage and tube well water irrigation with different fertilizer levels on rice and soil properties. *J. Indian Soc. Soil Sci.,* **44** (3) : 547-549.

Tiwari, R.J., Bangar, K.S., Nema, G.R., and Sharma, R.K. (1998). Long term effect of pressmud and nitrogenous fertilizers on sugar cane and sugar yield on a Typic Chromustert., *J. Indian Soc. Soil Sci.,* **46** (2) : 243-245.

Totawat, K. L.(1991). Effect of effluent from Zinc smelter on metallic cations in soil and crops in cropping sequences. *J. Indian Soc. Soil Sci. 39 : 542-548.*

Tripathi, B.D. and Ambasht, R.S. (1981). Changes in the morphological behaviour of wheat plants grown on polluted habitats. *Geo-Eco. Trop.,* **5** (3) : 211-218.

*Tripathi, B.D., Kumari, D. and Dwivedi, R.K. (1988). Effect of sewage irrigation on soil properties and yield of potato. *Geo. Eco. Trop.,* **12** (1-4) : 133-141. (Fide – *Soils and Fertil. Abstr.,* **54** (7) : 1093, 1991).

*Traka, M.E., Malovpa, E., Papadopulos, F., Papadopulos, A., Munoz, C.R.(1998). Response of green house tomatoes to waste water fertigation in soil less condition. *International symposium on water quality and quantity in green house horticulture,* Tenerife, Canary Islands., 5-8 November, 1996 (Fide *Acta Horticulture.,* **458** : 411-415.

Trivedi, B.S., Bhatt, P.M., Patel, M and Gami, R.C. (1995). Increasing efficiency of fertilizer phosphorus through addition of organic amendment in groundnut. *J. Indian Soc. Soil Sci.,* **43** (3) : 627-629.

Trivedi, R.K. and Goel, P. K. (1984). Chemical and biological method for water pollution studies, *Environ. Pub.,* Karad, India.

Vigerust, E. and Selmer Olsen, A.R. (1986). Basis for metal limits relevant to sludge utilization. In :. Factor influencing sludge utilization practice in Europe (*Davis, R.D. Haeni, H. and Hermite, P.(ed). Elsevier Applied Science Publisher Ltd. Barking,* pp. 26-42.

*Williams, C. H. and Steinbergs, A. (1959) Soil sulphur fractions as chemical indices of available sulphur in some australian soils. *Aust. J. Agric. Res.,* **10** : 340

Webber, L.R. (1978). Incorporation of non segregated, non composed solid waste and soil physical properties. *J. Environ. Qual.,* **7** (3) : 397-400.

World Health Organisation (1989). Health guidelines for the use of waste water in agriculture WHO. *Tech., Rep. Ser.* GENEWA.

Yaduvanshi, N.P.S. and Yadav, D.V. (1996). Residuall effect of pressmud cake with nitrogen on cone yield, juice quality and soil nitrogen in sugarcane ratoon. *J. Indian Soc. Soil Sci.,* **44** (1) : 158-160.

*Yang, S.C. (1968). Effect of Spent wash on soil chemical and physical properties and sugarcane yield. *Soils. Ferti. Taiwan.,* **71** : 25-29.

Yoder, R.E. (1937). Wet sieving method (Agreycte size). *Proc. Soil Sci., Soc. Am.* : **20**-21.

*Yoshika, S.I. (1981). Studies on applying waste water discharges from potato starch factories to arable land. *Res. Bull. Hokkaido. Nat..Agric.Exp.,* **130** : 99-112 (Fide-*Fld. Crop Abstr.* **35** (10) : 847, 1982).

*Zabek, S. (1976). Content of macro and micro-elements in crops irrigated with diary plant sewage. *Rocziki. Nauk Rolniczych,* **101** (3) : 71-78 (Fide-*soisl and ferti. Abstr.* **39** (12) : 693, 1976).

Zalawadia, N.M. and Raman, S. (1994). Effect of distillery waste water with graded fertilizer levels on sorghum yield and soil properties. *J. Indian Soc. Soil Sci.,* **42** : 575-578.

---

*Original not seen

CERTIFICATE

This is to certify that I have no objection for supplying only one copy or any part of this thesis to any scientist at a time through reprographic process if necessary for rendering reference service in a library or documentation center.

(H. V. MATHAKIYA)

Place: Navsari

Date: 13th May, 2002