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**AGRONOMIC INVESTIGATION ON USE OF
DISTILLERY EFFLUENT ON THE PERFORMANCE
OF RABI MAIZE AND WHEAT**

SUKANYA, T.S.

**DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580 005**

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**AGRONOMIC INVESTIGATION ON USE OF
DISTILLERY EFFLUENT ON THE PERFORMANCE
OF *RABI* MAIZE AND WHEAT**

Thesis submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfilment of the requirements for the
Degree of

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IN
AGRONOMY**

By
SUKANYA, T.S.

**DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580 005**

JANUARY, 2002

**DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD-580 005**

CERTIFICATE

*This is to certify that the thesis entitled "**AGRONOMIC INVESTIGATION ON USE OF DISTILLERY EFFLUENT ON THE PERFORMANCE OF RABI MAIZE AND WHEAT**" submitted by Miss. SUKANYA, T. S., for the degree of DOCTOR OF PHILOSOPHY in AGRONOMY to the University of Agricultural Sciences, Dharwad, is a record of research work carried out by her during the period of her study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

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MAJOR ADVISOR

Approved by :

Chairman :


(S. S. MELI)

Members :

1. (C. S. HUNSHAL)

2. (A. R. ALAGAWADI)

3. (H. T. CHANNAL)

4. (S. M. HIREMATH)

***Affectionately
Dedicated
to
my beloved brother
Dinesh Kumar***

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Introduction

I. INTRODUCTION

Efficient utilization of water and land resources is crucial to crop production for meeting the challenge of feeding the ever increasing human population. Besides meeting the food requirement, the modern agriculture is also responsible for development of large number of industries specially the agro-based industries, through supply of wide variety of raw materials for these industries. Although industrialization is believed to be the index of modernisation, it has its unavoidable effect on pollution of air, water and soil depending upon the type of industry, nature of raw material used and the manufacturing process involved (Hodges, 1973). Since the industrialization and pollution are complementary to each other, necessary steps are to be taken for disposal of the pollutants.

Among many industries, distillery units producing alcohol is one of the major revenue earning enterprise for Government. Alcohol is produced from sugarcane molasses. The molasses is fermented with yeast and alcohol is distilled from fermented wash leaving behind spent wash. During the recent years, India has emerged as the largest sugar producer of the world. Being a byproduct of sugar industry, alcohol bears immense significance as a raw material for rapidly advancing chemical industry, export potential and as a source of energy. Looking to the present scenario as well as for future, demand for alcohol will increase in the country and so also the number of distilleries producing alcohol. This is clearly evident from the two fold increase in number of alcohol industries in India during the last decade. Presently, there are 285 distilleries in India (AIDA, 1995) and the annual alcohol production in India had reached 2.7 billion liters. The proportion of

waste water generally known as 'Spent wash', is nearly 15 times of the total alcohol production. The evaporation of the spent wash results in a solid material called "distillery sludge". The distillery sludge is reported to have high quantities of both macro and micro nutrients (Miller, 1973).

Green revolution in India has brought a phenomenal rise in fertilizer consumption from 0.75 million tonnes to 18 million tonnes during 2000 (Anon., 2000). Yet nutrient supply is the major constraint in the development of Indian agriculture as there is excess mining of nutrients i.e., removal of N, P and K by crops is more than their replenishment with fertilizers and/or other organic sources. For maintaining optimum productivity of the land and building up of soil fertility, the use of organic manures to crops needs no emphasis. It is a well known fact that the availability of organic manure is very much limited in the present day agriculture due to population explosion, intensive agriculture, reduction in livestock population etc. Therefore, the application of nutrients need to be increased to keep the soil fertile and make agriculture sustainable. But the cost of inorganic fertilizer is increasing. The other fact is that the plant takes up 16 elements of which C,H, O are available in nature, but remaining 13 elements have to be provided through soil only. But what is in practice is application of NPK and that too not balanced. The other 10 elements which are normally supplemented through organic sources are not being adopted due to non-availability, labour consuming, expensive etc. This calls for use of alternate sources of nutrients in agriculture.

The agricultural waste materials, crop residues and animal wastes are being applied to land as source of nutrients. Recently industrial wastes and

byproducts are being applied to agricultural land to substitute nutrient requirement in crop production. The distillery effluent being a plant extract (sugarcane), it hardly contains any heavy metals and other toxic substances (Eyini *et al.*, 1993). Also it is known to contain many plant nutrients (Manonmani *et al.*, 1990), making it a potential substance for irrigation and nutrition but is characterized by high biological oxygen demand and chemical oxygen demand.

The use of distillery effluent either in liquid or solid form in agriculture has been practiced in India since the inception of the industry. In certain areas, the scarcity of water has forced the farmers to use the effluent as a substitute for irrigation water but over the years, use of this has led to realization of its manurial potential also. Since the conventional methods of waste treatment are of uneconomical and there is a difficulty to handle in large quantities, alternative methods like application of distillery effluents to agricultural land is receiving increasing attention. This is supposed to solve the problem of waste disposal as well as source of irrigation water and nutrients for crop production.

The manurial value of distillery effluent can profitably be used as supplement to the fertilizer when used along with irrigation water (Jadhav and Savant, 1975). Twenty five per cent of the recommended fertilizer can be saved by irrigation with distillery waste water along with 75 per cent of the recommended fertilizer application (Zalawadia and Raman, 1994). The discharge of spent wash into natural streams of water lowers the pH of water, depletes the oxygen content and subsequently destroys the aquatic life. Whereas, discharge of this on land causes accumulation of toxic salts, charring of vegetation and crops and finally produces unpleasant smell (Patil

et al., 1987). Hence, this needs to be handled and used with scientifically proven method. Moreover, the problems which each distillery unit faces are unique and different. Hence, different strategies and approaches have to be followed in finding a solution to distillery effluent disposal from each distillery unit.

One such distillery unit selected for study was of Sri Lakshmi Narayana Distillery Unit, located near Garag village, about 12 km away from Dharwad city, Karnataka. The farmers around the factory are utilizing lagooned and diluted effluent without knowing its effect on soil and crop. There are some apprehensions that application of distillery effluent might cause deleterious effect on soil properties and crop productivity. The preliminary analysis of both solid and liquid effluents has indicated that they contained good amount of primary and secondary nutrients. Therefore, to find a solution for effective utilization of distillery effluent in agriculture, a field experimentation on "Agronomic investigation on use of distillery effluent on the performance of *rabi* maize and wheat" were conducted for two consecutive *rabi* seasons with the following objectives :

1. To study the suitability of solid and liquid effluent as a source of nitrogen fertilizer,
2. To study the effect of conjunctive use of distillery effluent as a source of irrigation with good water,
3. To study the effect of use of distillery effluent on growth, yield and quality of crops and
4. To study the effect of distillery effluent on physico-chemical properties of the soil.

Review of Literature

II. REVIEW OF LITERATURE

In an effort to know the “Agronomic investigation on use of distillery effluent on the performance of *rabi* maize and wheat”, a review of the past work on several aspects of distillery effluent and its use in crop production is made here. The literature compiled focused on

2.1 Composition of distillery effluent

2.2 Use of distillery effluent as a source of nutrients

2.3 Use of distillery effluent as a source of irrigation

2.4 Effect of distillery effluent on growth, yield and quality of crops

2.5 Effect of distillery effluent on soil physico-chemical properties

2.6 Effect of distillery effluent on soil nutrient availability and uptake by crops

2.7 Effect of different effluents on soil properties and crops and

2.8 Effect of sewage water irrigation on growth, yield and quality of crops.

2.1 Composition of distillery effluent

The byproduct of distillery industry is spent wash. It is also called potale, stillage vinasse, detritus and dunder. After evaporation of spent wash, the left over solids is called distillery sludge. Depending upon the nature of molasses and chemicals used in manufacturing rectified spirit, the composition of distillery waste varies.

On an average evaporated spent wash was reported to contain a dry matter of about 30.5 per cent. While major plant nutrients N, P and K

were 3.68 per cent, 1.1 per cent and 1.1 per cent, respectively. The Ca, Mg and Na contents were 0.45 per cent, 0.50 per cent and 0.035 per cent, respectively (Miller, 1973).

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

Jadhav and Sawant (1975) while studying the effects of spent wash on physico-chemical properties of soil, analysed the spent wash for its chemical composition. The value for different constituents were, pH : 8, EC (dSm^{-1}) : 31.0, total N : 1,400 ppm, total P : 1225 ppm, total K : 13,600 ppm, total Ca : 100 ppm, total Mg : 1,700 ppm and chemical oxygen demand (COD) : 13,000 ppm.

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

Whiskey spent wash had a biological oxygen demand (BOD) of 34,500 and COD of 47,000 ppm and it had the organic and nitrogen content of 26,500 ppm and 3040 ppm, respectively. The pH of the whiskey spent wash was 3.3 (Quinn and Marchant, 1980).

Savant *et al.* (1980) evaluated chemical nature of spent wash solids (SWS) and FYM and reported that SWS contained more ether soluble, alcohol soluble and hot water soluble fractions than FYM and further contained more of inorganic nitrogen and less unhydrolysable nitrogen

than FYM, while it was poor source of total as well as organic and inorganic phosphorus as compared with FYM. However, the total potassium content of SWS was about 12 times more than FYM.

Robertiello (1982) analysed the chemical constituents of vinasse. According to his findings, cane vinasse had a pH of 5.4, BOD of 57,400 ppm and COD of 1,03,000 ppm. The other constituents were; total N : 1190 ppm and total P : 120 ppm.

Molasses distillery spent wash solids had a total N, P and K of about 2 per cent, 0.28 per cent and 9.98 per cent, respectively (Savant *et al.*, 1980).

Naylor and Severson (1984) analysed the brewery sludge for different constituents and the values were; total N: 2.59 per cent, total P : 0.64 per cent, total K : 0.11 per cent, Ca : 16.8 per cent, Mg : 0.37 per cent, Na : 0.20 per cent and pH : 11.3.

Kulkarni *et al.* (1987) stated that spent wash was a major pollutant because of its high organic contents. They classified spent wash as dilute liquid organic fertilizer with high K content and further reported that it contained about 90 to 93 per cent water and 7 to 9 per cent solids. The 75 per cent of solids were organic and 25 per cent were inorganic. Its N content was mostly in colloidal form which behaved as a slow release fertilizer and it was better than other inorganic N source. The two third of P was in organic form and the metabolic availability of which was more than any important inorganic source. Moreover, it contained large amount of important secondary elements such as Ca, S and Mg as well as Cu, Mn and Zn. It contained 29.06 per cent reducing sugar, 9.0

protein, 1.5 per cent volatile solids, 21.0 per cent gums, 4.5 per cent combined lactic acid. 1.5 per cent combined organic acids, 5.5 per cent glycerol and 15.0 per cent wax and phenolic bodies.

Patil *et al.* (1987) stated that spent wash was highly acidic and carried a huge organic load and total solids. It contained a good amount of K and high concentration of chlorides and sulphates. Spent wash was highly viscous and corrosive type of liquid. They opined as spent wash is rich in highly putricible organics, the waste water as it flows through water stream decompose rapidly giving obnoxious odour which makes nuisance and environment filthy and life of the people living nearby the distillery miserable.

Cerri *et al.* (1988) reported that vinasse had the highest content of organic N, nutrients and ash while bagasse contained the least. Organic compounds extracted by alkaline reagents were of humic nature and were similar to those in soil except that fulvic acid predominated over humic acid.

While studying the effect of distillery effluent on seed germination and seedling growth of rice, Rajaram and Janardhanan (1988) analysed the effluent for different constituents. The results indicated 18 ppm N, 34,650 ppm BOD, 1,13,095 ppm COD and a pH of 4.7.

Anaerobically digested effluent from molasses residue had the elemental concentration of total N : 21,300 ppm, P : 4,000 ppm K : 1,20,000 ppm, Ca : 32,000 ppm, Mg : 18,000 ppm and Na : 14,000 ppm (Sweeney and Graetz, 1988 and 1991).

Chang and Li (1989) reported that vinasse contained 16 per cent organic matter and 1 per cent K_2O . Presence of sugars (2-20%) and proteins (10 to 11%) in the dry spent wash along with mineral component as observed by Kulkarni *et al.* (1990).

One of the agro industrial waste materials brewery industry is brewer's spent grains (BSG). Mbagwu and Ekwealor (1990) while studying agronomic potential of BSG found some of the chemical characteristics of BSG. They were; organic carbon : 21 per cent, total N : 5.1 percent, available P : 0.4 per cent, K : 3.4 per cent, Ca : 0.4 per cent, Mg : 0.48 per cent besides a pH of 4.4 and C : N ratio of 21.5.

Bhat (1994) analysed the distillery effluent of Ugar Sugar Works Ltd., Ugarkhurd and reported that pH of raw spent was acidic (4.03) which increased to 7.62 during Lagooning. It also contained large amount of suspended and dissolved solids having high concentration of BOD and COD. Whereas, the content of Ca, Mg and K was higher than Na. However, BOD and COD of effluent was found to be drastically reduced by lagooning and diluting with Krishna river water

Joshi *et al.* (1996) found that the distillery effluent contained large amounts of organic matter, N, P, K, S, Ca and further contained a high salt load, sulfates and chlorides of K, Na and Ca. The distillery effluent contained a considerable amount of plant nutrients (Pathak *et al.*, 1999).

2.2 Use of distillery effluent as a source of nutrients

Bajpai and Dua (1972) suggested the use of distillery effluent as a nitrogen source by obtaining a significantly higher yield in sugarcane with

200 kg N through spent wash application. The manurial value of distillery effluent can profitably be used as supplement to the fertilizer when used along with irrigation water (Jadhav and Sawant, 1975). The use of effluent water has indicated that 25 per cent of the recommended dose of fertilizer nutrients can be saved in this way which not only solve the problem of disposal but substitute some quantity of inorganic fertilizers.

Dongale and Sawant (1978) opined that spent wash was as good as potassium chloride (KCl) as a source of potassium for sorghum. The evaluation of stillage as a source of K for maize (*Zea mays* L.) in comparison with KCl and potassium sulphate (K_2SO_4) was done by Berton *et al.* (1983) and they found that the availability of K in different concentration (0,75,150,225 and 300 mg/dm² soil) was similar to that in KCl and K_2SO_4 .

Distillery waste could be safely used as fertilizer along with irrigation water (Goel and Mandavekar, 1983). *Cymopsis tetragonoloba* irrigated with 10 per cent distillery waste showed more nodulation. But higher concentration suppressed the nodulation and growth.

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

Brewery sludge residuals are approximately equivalent on a dry basis to fertilizer with an analysis of 3 : 1 : 0 (N:P₂O₅:K₂O). It is estimated

that a single application of 5 to 20 dry tonnes per acre will increase overall hay yields over one year period by a factor of at least 5 times as compared to untreated hay fields (Naylor and Severson, 1984).

Chares (1985) reported that the distillery effluent is used as a complement to mineral fertilizer to sugarcane in Brazil. The distillery effluent contained N, P, K, Ca, Mg and S and it is thus valued as a fertilizer when applied to soil through irrigation water (Samuel, 1986)

Kulkarni *et al.* (1987) classified spent wash as dilute liquid organic fertilizer with a high potassium contents and its nitrogen was mostly in colloidal form behaving as a slow release fertilizer better than most chemical nitrogen sources. Further, they stated that the availability of phosphorus was more than any chemical sources besides containing large amount of important secondary elements like Ca, S and Mg as well as trace elements such as Cu, Mn and Zn.

Webb and Chapman (1987) and Paula *et al.* (1989) found spent wash as a reliable substitute for muriate of potash for sugarcane and potato.

The spent wash treated by aerobic composting technology was used as manure (Khambe *et al.*, 1992). The maximum manuring rate was found to be 60 t per ha, above which earthworms were found affected. It was also observed that the introduction of spent wash compost leachate in water streams enhanced the growth of algae and did not cause any toxic effects on the aquatic fern. The distillery effluent can be considered as liquid manure and controlled application of the treated effluent can increase the productivity of sugarcane and sugarbeet (Devarajan *et al.*, 1994).

Zalawadia and Raman (1994) reported that 25 per cent of the recommended fertilizer can be saved by going for irrigation with distillery waste water along with 75 per cent of the recommended fertilizer application in onion. The total dry matter and yield obtained was at par with 100 per cent recommended dose of fertilizer application with normal water irrigation and further percentage utilization of applied N, P and K through fertilizer were more in distillery waste water with 75 per cent fertilizer dose.

Joshi *et al.* (1996) stated that the distillery effluent containing large amounts of organic matter, N, P, K, S and Ca was used for crop production in India as an alternative source of nutrients, thereby reducing investment on inorganic fertilizers. However, the effluent contained a higher salt load, comprising sulfates and chlorides of K, Na and Ca, which might result in negative environmental impacts if used continuously.

The distillery effluent could be used as soil amendment as it increased the yield of wheat and rice grown in sequence and further improved the soil physico-chemical properties (Pathak *et al.*, 1999). Phanapavudhikul (1999) stated that the farmers could save 66 – 80 P per m³ in terms of equivalent chemical fertilizer. The direct use of spent wash liquor is promising trend towards sustainable development in developing countries.

From the references given above, it can be inferred that the distillery waste either in liquid or solid form could be judiciously used as a source of nutrients for crops.

2.3 Use of distillery effluent as a source of irrigation

Escolar (1966) observed increased yield in snapbean due to application of spentwash. Distillery effluent contained an excess of various forms of cations and anions and concentration of these should be reduced to beneficial level by diluting the effluent which can be used for irrigation purpose (Sahai *et al.*, 1983).

Guruswamy (1986) reported that the effluent from lagoon, after dilution can be used successfully to irrigate sugarcane, wheat, barley and elephant grass and the only disadvantage is that it requires enormous water for dilution.

A study on the effect on distillery effluent on seed germination, seedling growth and chlorophyll content in sunflower (*Helianthus annuus* L.) var EC 68414 revealed decreased seed germination, seedling growth and chlorophyll content with increased effluent concentration (Rajendiran, 1990). His study revealed that the distillery effluent could safely be used for irrigation purpose at low concentration upto 25 per cent.

Devarajan *et al.* (1993) registered significantly higher sugarcane yield in COC. 771 at 50, 40, 30 and 20 times diluted effluent irrigations than irrigated with normal water.

Devarajan and oblisamy (1994) opined that the higher dilution could be used for irrigation purpose without adversely affecting soil fertility and crop productivity. The effluent irrigations improved the physical and chemical properties of the soil and further increased soil

micro-flora there by producing ideal conditions for cane cultivation (Devarajan *et al.*, 1994). Machado-de-Armas *et al.* (1994) found irrigation with distillery effluent increased soil Mg and Na contents in sugarcane soils.

A lower concentration of effluent enhanced both peak value of germination and mean daily germination of *Albizia procera* whereas the higher effluent concentration inhibited both the parameters progressively (Pandey and Soni, 1994). Zalawadia and Raman (1994) revealed that there was a positive influence of distillery waste water on sorghum yield.

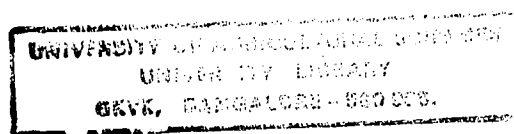
Devarajan and Oblisamy (1995) found sugarcane variety Co. 853 registered significantly higher cane yield by 14.6 and 8.3 per cent at 50 and 40 times dilutions, respectively when compared with irrigation purely by water. Thus, they recommended 50 times diluted effluent as suitable for irrigating the crop. Pujar (1995) studied that the distillery effluent could be used as a source of irrigation at higher dilutions. For wheat, 50 times dilution proved better but for maize and sugarcane, a lower dilution of distillery effluent (10 times) proved superior. Further in wheat crop, at 10 times dilution produced more chaffy and unfilled nature of grains due to excessive nutrients application particularly nitrogen.

Singh *et al.* (1995) stated that the irrigation of crops with distillery effluent had no adverse effect on the germination of wheat maize, sorghum and cowpea infact, it had beneficial effects as compare to irrigation with fresh well water. Irrigation in standing crop of wheat was done with dilution of the effluent by bringing down the BOD to 500 mg per litre which was found to be safer for irrigation in wheat.

Babu *et al.* (1996) revealed that as the spent wash does not contain heavy metals may be used as a source of irrigation by going higher dilutions with normal water. The usefulness of distillery waste water for irrigation purpose and saving of fertilizer to the extent of 25 per cent in onion found by Zalawadia *et al.* (1996) in light textured soils.

Singh and Raj Bahadur (1997) found maize crop withstood irrigation done with five times diluted effluent. This diluted effluent irrigation had positive effect on crop growth and soil productivity. Plants in five times diluted effluent irrigated plots were significantly taller and other growth parameters were also on higher side than higher diluted effluents irrigated plots. They concluded that effluent upto 1000 mg per litre BOD can be safely used for irrigating maize which left a positive effect on soil fertility. Singh and Raj Bahadur (1998) conducted an experiment to utilise distillery effluents having biological oxygen demand of 4,620 mg per litre for pre-sowing irrigation. They found that 12 pre-sowing irrigations had no adverse effect on germination of maize but improved the growth and yield. In the areas wherever distillery effluent available, it should be diluted 50 or more than 50 times with irrigation water to increase the rice yield without having any detrimental effect on soil health (Annadurai *et al.*, 1999).

From these reviews, it can be inferred that the liquid distillery effluent could be safely used as a sources of irrigation water provided dilution with water. Further, different crops responded differently to diluted distillery effluent.



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2.4 Effect of distillery effluent on growth, yield and quality of crops

2.4.1 Effect on cereals

Bucknall *et al.* (1979) reported that total annual application of potale (waste product of malt whisky distillery) of $>100 \text{ m}^3$ per ha increased the dry matter yield of lowland grass and grain yield of barley. Application of 220 m^3 per ha potale gave higher grain yield ($5,000 \text{ kg/ha}$) over no potale applied plot ($2,900 \text{ kg/ha}$). Number of ears per m^2 area and 1000 grain weight were also increased (554 and 42.9 g) over control (445 and 39.0 g).

In a pot culture experiment, pre-treatment of urea and rock phosphate fertilizers with brewery effluent, significantly increased the grain yield of ragi (34.73 g/pot) over untreated fertilizers (26.25 g/pot) (Shailendranath and Rao, 1979).

Jabeen *et al.* (1987) studied adverse effects of distillery effluent on growth parameters of wheat. They found a marked decrease in the growth parameter of wheat from non polluted station to the moderately polluted one. No plant could survive at highly polluted station. They attributed this adverse effect to the excessive concentrations of various injurious cations, anions and organic pollutants present in the effluent.

As reported by Mbagwu and Ekwealor (1990) the application of 2.5 per cent brewers spent grains (BSG) increased the plant height and dry matter of maize from 45.1 cm and 1.77 g per pot in the treatment receiving complete fertilizer (60 : 15 : 60 : 20 ppm of N : P : K : Mg/pot) to 68.3 cm and 5.12 g per pot.

Shankarappa (1993) observed from the very beginning, combination of distillery sludge with inorganic source improved the overall growth and registered significantly higher plant height, dry matter and yield at 10,000 kg per ha distillery sludge along with recommended dose in finger millet.

Pujar (1995) recorded highest grain yield in wheat at 50 times and maize at 10 times dilution of effluent irrigation. Twelve pre-sowing irrigations with the distillery effluent had no adverse effect on the germination of maize but improved the growth and yield (Singh and Raj Bahadur, 1998).

In a field study, soil amended with diluted post methanation distillery effluent increased the yield of wheat and rice growing sequence (Pathak *et al.*, 1999). Phanapavudhikul (1999) found when digested liquor which was diluted and pumped during the dry season (December to July) to 400 ha of paddy field resulted in a 2 – 3 fold increase in rice yield.

2.4.2. Effect on Pulses

Effluent concentration upto 5 per cent was found beneficial for over all growth of mung (*Phaseolus radiatus*), pigeonpea (*Cajanus cajan*) and chickpea (*Cicer ariatinum*). An increased concentration resulted in retarded growth of all these crops (Sahai *et al.*, 1985; Sahai and Neelam, 1987; Sirivastava and Sahai, 1987; Mukherjee and Sahai, 1988). But for cowpea, blackgram and mungbean upto 2.5 per cent concentration was found beneficial (Rajaram and Janaradhanan, 1988; Vijayakumari and Kumuda, 1990). In soybean, the use of distillery effluent at any rate was found detrimental (Rajaram and Janardhanan, 1988).

Rani and Srivastava (1990) while studying the impact of various concentrations (10, 25, 50, 75 or 100% v /v) of distillery effluent on growth of peas, found that shoot length, leaf number per plant, leaf area, chlorophyll content and phytomass exhibited a gradual increase upto 25 per cent. However, the effluent at all concentrations inhibited root growth. The number of pods per plant, seeds per pod and seeds per plant in peas increased upto 25 per cent concentration, but seed chlorophyll content was highest (15.73%) with 10 per cent concentration.

Goyal Sneh and Kapoor (1995) reported that application of distillery waste water upto 160 m³ per ha lead to increase in dry matter production of mungbean and further increase in level of distillery waste water led to increase in dry matter production. However, application at 640 m³ per ha, declined the dry matter drastically and was even less than the control.

Babu *et al.* (1996) found that application of the spent wash without dilution did not result in growth deformities or any alternation in plant metabolism. Significant increase in all plant growth attributes were observed. Further they noticed increased total chlorophyll, phenols, pigments, proteins, amino acids, starch and nitrogen contents in the leaves in treated plants.

2.4.3 Effect on oil seed crops

Asha Juwarkar and Dutta (1983) reported that irrigation of groundnut plants with raw distillery waste water resulted in a reduction of nodulation and absence of fruit formation of the plant. This inhibitory effect was reduced when raw waste water was diluted to 50 per cent by tap water.

Rajendiran (1990) studied the effect of distillery effluent on seed germination, seedling growth and chlorophyll content in sunflower (*Helianthus annuus* L.) variety EC 68414. He found a decreased seed germination rate and chlorophyll content with increased effluent concentration.

2.4.4 Effect on cash crop

In sand culture studies, the growth and chemical composition of sugarcane were not adversely affected by spent wash solids applied at 250 ppm (Jagdale and Sawant, 1979). But higher rates were found detrimental. An increase in ash and K content of raw and clear cane juice and molasses by application of vinasse (Rodella and Ferrari, 1977) was observed.

Silva *et al.* (1981) reported that application of 80 m³ per hectare vinasse alone considerably improved the yield of cane and sugar per hectare. Significant increase in cane yield and recoverable sugar per hectare due to application of spent wash at the rate of 90 to 150 tonnes per hectare was observed by Viera (1982).

Madrod *et al.* (1986) observed that the levels of vinasse increased cane and sugar yield, but reduced pol content, apparent purity, brix and sugar yield. The stand of leguminous intercrop with cane was reduced by vinasse applied at a very early stage of plant growth. The application of vinasse at the rate of 120 m³ per hectare accelerated cane ripening and increased cane and sugar yield per hectare (Barrocal, 1988). The increase in sugar yield was 2.07 tonnes per hectare over control.

Mohan Singh *et al.* (1993) observed juice quality parameters such as pol per cent and purity coefficient remained unaffected on addition of 500 m³ distillery effluent. Devarajan and Obisamy (1995) recorded the highest cane yield of 182.8 tonnes at irrigation with distillery effluent diluted to 50 times. However cane yield and juice quality decreased with increasing concentration of the effluent in irrigation water. Best results were obtained (Ghugare and Magar, 1995) when 50 times diluted vinasse was applied at 16 t per ha, the cane yield (188.1 t per ha) and commercial cane sugar yield (25.96 t/ha) were 20 per cent higher than control values (155.9 and 20.94 t/ha). Juice quality was better than that from control. The cane: brix pol and purity were highest when applied with 32 t per ha of diluted 50 fold, while the N:P₂O₅ ratio was lowest with 32 t per ha diluted 75 – fold.

Pujar (1995) registered highest sugarcane yield with 10 times dilution when affluent amended along with the pressmud. But the quality parameters in sugarcane were not influenced due to diluted effluent irrigation. Zalawadia *et al.* (1997) found that the application of spent wash diluted at any level increased sugarcane yield. Less diluted spent wash gave a greater yield of biomass than the more diluted ones.

2.4.5 Effect on grasses

Sweeney and Graetz (1991) in their lab experiments investigated the effect of 0, 22. 44 and 88 g of effluent per pot on growth of Augustine grass (*Stenotaphrum secundatum*) for 8 months. During the initial 4 months, *S. secundatum* dry matter yield was >60% higher with the 2 lower application rates than with the higher rate or in the control. At the end of 4 months the highest treatment had caused chlorosis and tissue drying.

From all the reviews, it can be concluded that the distillery effluent could be safely used for crop production without any adverse effect on plant growth. Further, use of distillery wastes upto certain extent increases growth and yield. However, when indiscriminately used plant growth and yields were affected.

2.5 Effect of distillery effluent on soil physico – chemical properties

2.5.1 Physical properties

Escolar (1963) observed changes in hydraulic conductivity, aggregate stability and improvement in infiltration rate by addition of distillery slops and molasses to column of saline sodic soil. Epstein (1975) observed that the infiltration rate in soil was reduced due to crust formation on surface layer. The water movement was thus restricted due to clogging of pores.

Jadhav and Sawant (1975) have reported that the physical properties of soil like water retention, hydraulic conductivity and water stable aggregates were adversely affected with irrigation of distillery effluent. Vinten *et al.* (1983) opined that the reduction in hydraulic conductivity was due to accumulation of solids at the surface.

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

Rachhapal *et al.* (1980) concluded that addition of spent wash without dilution was very effective in increasing the water intake rate of

sodic calcareous soil. Application of spent wash followed by irrigation rather than dilution of spent wash at the time of its application was very effective in reclamation of sodic soil. Shinde *et al.* (1993) have noticed improvement in stability of aggregates and porosity due to application of spent wash solids and spent wash-pressmud compost.

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

2.5.2 Chemical properties

Incubation studies conducted by Jadhav and Sawant (1975) indicated that the application of spent wash increased pH, EC, cations, anions, sodium adsorption ratio (SAR), potassium adsorption ratio (PAR), exchangeable Na and K and decreased exchangeable Ca and Mg. Significant rise in COD of saturation paste extract of soil was observed. Increased potassium content in soil was observed when soil was treated with spentwash (Dongale and Savant, 1979; Perez Escolar and Ortiz Velez, 1979; Vicente-Chandler *et al.*, 1984 and Shankarappa, 1993).

Nunes *et al.* (1981) applied increasing levels of spent wash and observed that total N, C levels and exchangeable Na were not affected and exchangeable K, Ca, Mg and pH were increased. While, exchangeable Al, available P and NO₃ decreased. Mineralization of organic material as well as nutrients present in the effluents were responsible for increased availability of plant nutrients (Somashekär *et al.*, 1984).

Orland *et al.* (1985) applied vinasse for 20 years and found that soil was benefited in terms of pH increase, higher K, Ca and Mg content and greater CEC. Guruswamy (1986) stated that discharge of untreated spent wash on land lowered soil pH and waste water produced in the distillery carried a high organic load which caused severe fouling of atmosphere.

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

Taluk and Medeiros (1989) also observed increased soil pH, available N, P, K, Ca and Mg by 80 m³ vinasse application per hectare. Irrigation to cane field with distillery effluent effected tendency for exchangeable calcium to increase.

Sweeny and Graetz (1991) found that addition of distillery effluent regardless of rate, raised the soil pH, owing to increase in soil K, Ca, Mg and Na content. Further, they noticed that digested distillery effluent application increased soil concentrations of most elements.

Pawar *et al.* (1992) found that addition of diluted spent wash decreased pH and EC. There were significant changes in exchangeable K, Ca and Mg. Further, the DTPA extractable Fe and Mn of soil was significantly increased at all stages of crop growth treated with diluted spent wash.

Shinde *et al.* (1993) observed increased EC and available K in soil and saturation paste extract when applied with spent wash solids.

Further, increased available N, P and DTPA extractable Fe, Mn and Zn in the soil at harvest of sorghum.

Bhat (1994) studied that the EC, SAR and available nutrient status of soil receiving diluted effluent were higher compared to soils irrigated with only water. Correlation studies made by Machado-de-Armas *et al.* (1994) in sugar cane soils irrigated with distillery effluent found that pH was strongly correlated. Mg and Na were the main cations affecting soil pH. Available P and exchangeable cations with the exception of Ca, were positively and organic matter was negatively correlated with soil pH. Irrigation with distillery effluent increased soil Mg and Na contents.

Zalawadia and Raman (1994) recorded higher values of electrolyte conductivity, organic carbon, available N, P and K with the usage of effluent water than with normal water at the same level of fertilizer application. Soil fertility was built up by the effluent application particularly soil organic carbon and potassium status (Singh and Raj Bahadur, 1997). Further, with increase in the amount of effluent increased in pH, EC, available N, P and K were noticed.

Singh and Raj Bahadur (1998) found that the pH and electrical conductivity of the soil slightly increased. Whereas, the soil organic carbon, nitrogen, phosphorus and potassium contents increases significantly with increase in the number of pre-sowing effluent irrigation.

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

2.6 Effect of distillery effluent on soil nutrient availability and uptake by crops

Escolar (1966) observed increased yield and uptake of P, K and Ca by snapbean due to spent wash application. A significantly higher yield of sugarcane and increased available N content of soil was recorded with 200kg N through spent wash application (Bajpai and Dua, 1972; Agarwal and Dua, 1976). Further, decrease in sugarcane yield and available N with 300 kg N through spent wash application per hectare was observed.

In laboratory incubation studies, Dongale and Savant (1978) applied K at 1000 ppm through spent wash. They noticed that at the end of 60 days, the NH_4OAC extractable K was higher in spent wash applied soil (320 ppm) than in control (160 ppm). Uptake of K by Jowar was also higher in treated soil (21 mg/40 plants) than in control (9 mg/40 plants).

Chatterjee *et al.* (1979) said that FYM or decomposed straw applied at the time of planting did not release as much available N as green leaf manure (*Sesbani bispinosa* and *Ipomea crassicaulis*) or spent hop (waste from brewery factory) applied at 10 t per ha to four to five weeks before planting of rice in submerged soil. Spent hop released more N (65 ppm) than other bulky organic manure (64 ppm). Application of spent hop resulted in an increase in organic carbon (1.01 %), CEC (15.15 m eq/100g), P (8.7 kg/ha) and K (196 kg/ha) than over control (0.87 % organic carbon, 13.89 m eq/100 g CEC, 7.1 kg P/ ha and 193 kg K/ha).

Párez Escolor and Ortiz vilez (1979) found that the application of rum distillery waste at the rate of 6.2 cm slops, 18.6 cm slops and 31.0cm slops per ha contributed higher K content of 1.89, 5.66 and 9.44 m eq per

100g of soil respectively. The initial salt content was increased by about 23 per cent. After application of 6.1 cm of water, salt content was reduced to two thirds of the total salt content from top 60 cm soil in all treatments.

Uptake of N, P, K, Ca and Mg were higher by ragi (*Eleusine coracana*) when urea and rock phosphate fertilizers are treated with brewery effluent (703.5, 128.8, 467.0, 625.5 and 317.8 mg/pot) than when untreated (446.0, 65.3, 396.0, 550.3 and 90.3 mg/pot) (Shailendranath and Rao, 1979).

Velloso *et al.* (1982) reported that the application of distillery residues to the soil decreased the nitrate loss from soil. The soil treated with 400 m³ per ha of residue with addition of N and P, the leaching of nitrate was about 30 ppm less and the leaching of ammonium about 4 ppm more than in no-residue treatment.

Vicente- Chandler *et al.* (1984) studied the effect of distillery slops on rice and rice soils. Exchangeable and HNO₃ extractable K increased with increasing levels of slops, from a total of 313 kg per ha when no slops were applied to 699 kg per ha when 240 hl of slops were applied per ha weekly 12 week to 4 successive rice crops. Exchangeable NH₄ content of the soil and leaf contents of N, P, K, Ca and Mg were not affected by the levels of distillery slops. An increase in the K concentration of soil with increased rate of stillage application in potato field has been found by Paula *et al.* (1989). There was also increase in soil Ca and pH with upto 100 m³ stillage.

Vinasse (distillery waste) mineralises rapidly releases nutrients and thus maintains soil fertility. The Ca, S, N and P contents of soil were increased (Cruz *et al.*, 1991).

Sweeney and Graetz (1991) reported that application of distillery waste anaerobic digester effluent to soil at any rate significantly increased K, Ca, Mg, Na concentrations (65, 1780, 1460, 545 and 116 ppm) than in control (14, 40, 800, 133 and 13 ppm).

Pawar *et al.* (1992) while testing the possibility of improving the physico-chemical properties of a typical saline calcareous soil by the application of spent wash, revealed that nutrient supplying status of soil improved considerably as evidenced by the performance of sugar cane grown on this soil. Spent wash solids, farm yard manure and spent wash pressmud compost were equal in their effect (Shinde *et al.*, 1993). Further, they also found that spent wash pressmud compost was superior to other sources in respect of N, P, K, Fe and Zn uptake.

Goyal sneh and Kapoor (1995) observed that application of distillery waste water upto 160 m³ per ha led to increase in dry matter production of mungbean and increase in both N and P uptake. Whereas, further increase in level of distillery waste water led to decrease in both dry matter production and N and P uptake.

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

Bhat and Doddamani (1995) found when soils irrigated with diluted effluent for different periods had higher available N, P and K than soils irrigated with only Krishna river water and unirrigated soils and even they also found higher uptake of N, P and K in lesser diluted treatments.

Zalawadia *et al.* (1997) showed that application of spent wash diluted at any level increased cane yield and nutrient uptake significantly over irrigation with tube well water. They also observed increased nutrient availability of P, K and S considerably there by indicating the signs of improvement in some soil physical properties. Similarly increase in the soil available N, P and K content by pre-sowing irrigation with distillery waste was recorded by Singh and Raj Bahadur (1998).

2.7 Effect of different effluents on soil properties and crops

Blosser and Owens (1964) working on pulp mill effluents found that when sodium adsorption ratio of paper mill effluents exceeded 9.0, infiltration rate of soil was retarded. This was attributed to the sodium replacing calcium and magnesium from the exchange complex of soils resulting in the dispersion of soil aggregates.

Ben *et al.* (1965) reported that soil properties were not affected during the eight year period of irrigation with paper mill effluents without dilution.

Kolar and Mitiska (1965) reported that sulphite waste liquor derived from paper mill effluent increased the general microbial activity, humus content, sorption capacity and N contents of the soil.

Significant increase in uptake of total Mn, P, K and Mg by oats over three cuttings was reported by Hashmoto and Yokota (1965) with

increasing rates of application of paper mill effluent. They attributed it to the presence of readily decomposable sugars in the liquor which enhanced N and Mn uptake. Increased P and Mg uptake was ascribed to lignin and tannin content.

Studies made by Vercher *et al.* (1965) indicated that paper mill effluent was useful for very fine sandy loam soil and did not cause any detrimental effects to soil properties.

With addition of sulphite spent liquor, NH_4 became immobilized in the early stages due to N assimilation by micro-organisms, which rapidly consumed carbohydrates and organic acids present in sulphite spent liquor. Solubility of Fe-P increased in flooded soil due to addition of sulphite spent liquor. Sulphonic acid from sulphite spent liquor was not converted into sulphide in flooded soil (Takai and Oguma, 1966).

A highly acidic, rich in N with high BOD, sulphite waste liquor was adjusted to neutral pH and used for irrigation in paddy crop. The early crop growth was good but declined during later stages. But, continuous irrigation with this effluent decreased paddy growth. Yield was found to increase with increasing BOD of the water upto 50ppm (COD 200 ppm) but above 50 ppm, yield levels were decreased because of creation of reduced conditions and decreased pH in the soil which promoted the leaching of inorganic elements like Fe, Ca and Mg (Minami and Taniguchi, 1971).

Sullivan (1973) found that when effluent applied to soil through irrigation undergoes a variety of physical, chemical and biological transformations. Some contaminants become fixed in soil, others are held on exchangeable complex where plants can utilize them, while others may leach to the water table below.

Daniel and Bouma (1974) pointed out significant role of effluent solids (Waste waters of high and low carbon contents of simulated septic tank and simulated extended aeration) in increasing the pore clogging in low permeable clayey soils.

Sukovaty *et al.* (1974) reported that the application of beef feet slot effluent did not affect the concentration of Ca, Mg, Na and K in the forage sorghum.

Pearson (1975) mentioned that *Asperagus* yield was adversely affected by the application of high rates of (19 mm/day) vegetable processing waste water with higher COD value (7144 mg/litre). Reduction in yield due to irrigation with paper factory effluent as compared to river water was reported by Malleshappa (1979) in soybean and Sheshadri (1980) in finger millet. **The undiluted effluents from M/s Seshasayee paper and Board Ltd, and Venkatesh paper mills Ltd, Tamil Nadu caused an increase in the pH, organic matter and available nutrient contents of red and black soils. The percentage pore space in both the soils got reduced and water holding capacity of black soil increased due to effluents, whereas it decreased in red soil (Rajanan and Oblisamy, 1979).**

The effluents of a paper factory a automobile industry, a textile industry and food and paper industry were alkaline in nature and contained variable amounts of plant nutrients such as Ca, Mg, B, Fe and Cu. The raw effluents altered physico-chemical properties of treated soil and they were responsible for reduction in the rate of germination of seeds. Diluted effluents however showed a favourable effect on seedling growth (Somashekar *et al.*, 1984).

Juwarkar *et al.* (1987) found that mixing of pulp mill waste water with chlorination and hypochlorite waste water in 7:1, 4:1 and 3:1 proportions reduced the SAR from 18.8 to 11.1, 6.6 and 5.3, respectively without any appreciable change in total dissolved salts. Further soils of loamy sand, sandy loam, sandy clay loam and loam texture with good drainage may not exhibit salinity problem as the water having electrical conductivity of 2,000 to 3,000 dS m⁻¹ has been used successfully in many places.

The dry matter and yield of groundnut enhanced considerably due to application of Fe or Zn under effluent irrigation. The uptake of Na and Mg were reduced on addition of amendments under effluent irrigation while no significant increase was obtained with K and P. The Ca uptake was also enhanced (Pathmanabhan *et al.*, 1988).

Zinc smelter effluent wash used in a pot culture study with various dilutions and amendments to raise maize, sorghum, wheat and barley (Totawat, 1991). The dry matter production for maize, sorghum and barley significantly decreased when undiluted effluent was used. However, when effluent was diluted with water and used for irrigation, it increased dry matter yield of maize and barley and lowered the levels of available Fe, Mn and Zn build up in soil.

Narasimharao and Narasimharao (1992) indicated that the Bhadrachalam paper board industry effluent (Andhra Pradesh) could be safely used for irrigation to rice and cotton on alluvial soil having loamy to sandy loam texture. Whereas, for tobacco and chilli with this effluent water led to poor quality produce and reduced crop yield.

Palaniswami and Sreeramulu (1994) reported that effluents discharged from Seshasayee paper and Board Ltd, (Pallipalyan) used for irrigating sugarcane crop on 'Typic Hapustalf' for 15 years showed that pH, EC, organic carbon, CEC, exchangeable cations, available P, K, micronutrients and enzyme activities were more and there was practically no significant change in most of soil properties.

Growth, yield and grain quality parameters of triticale cultivation were studied by Aziz *et al.* (1998) with the use of treated oil refinery effluent. The performance of crop was better under treated oil refinery effluent compared with that under ground water. Further, they found three irrigations with Tanery effluent proved superior to four irrigation with treated oil refinery effluent for almost all the characteristics studied.

Sundaramoorthy *et al.* (2001) reported that the percentage of germination and the seedling growth of groundnut increased from one to ten percent concentrations of the fertilizer factory effluent and the other higher concentrations decreased the germination percentage and seedling growth. Whereas, the control seedlings showed highest fresh and dry weight than the effluent treated plants.

2.8 Effect of sewage irrigation on growth, yield and quality of crops

2.8.1 Growth and yield of crops

Higher yields of wheat, bengalgram, redgram, potato, cabbage, cauliflower, frenchbean, chilli, ginger, sugarcane and turmeric were obtained due to sewage irrigation in Poona (Talati, 1950). Barley, oat and wheat utilized the nitrogen in sewage effluent as efficiently as they utilized

the N in commercial fertilizer to produce higher grain yield and protein content in grain. Sewage water was superior than well water and water plus fertilizer to produce protein and grain. Municipal waste can be utilized to produce oats with grain yield, forage yield and grain protein contents equal to those obtained when oat were grown with well water along with suggested level of N, P and K (Day and Kirk Patrik, 1973). Average number of heads per unit areas and grain yield were higher in wheat plots that received waste water than grown with well water along with recommended N, P and K (Day *et al.*, 1975). Wheat grain contained more protein, alanine, histidine, isoleucine and proline under sewage irrigation. Bole and Bell (1978) reported that alfalfa was the most suitable forage crop for optimum utilization of waste water compared to grass species.

Severe inhibition of germination of sorghum and millet (*Panicum milliicum*) due to the application of sewage effluent was noticed by Sabey and Hart (1975). However three months after sewage irrigation, it showed no inhibition. Celery yield was significantly high due to sewage as well as nitrogen (0 to 150 kg/ha) application (Mahajan *et al.*, 1978).

Day *et al.* (1979) obtained more wheat grain yield when irrigated with the pump water and waste water mixture than pump water inspite of more lodging due to taller plants in the former. Both red canary grass and maize renoted large amount of waste water effectively in permeable soils (Marten *et al.*, 1980). Day *et al.* (1982) recorded taller plants and higher hay yields of alfalfa when irrigated with waste water and pump water mixture than pump water alone. Source of irrigation did not affect the total protein in hay. Vegetative growth and seed cotton yield were

high in sewage irrigated lands (Bielorai *et al.*, 1984). Sharma and Kansal (1984) recorded significantly higher dry matter production of maize and spinach by irrigation with sewage or mixed with canal water than pure canal water. Crowford (1985) reported an increase in the yield of maize (85-105 q/ha) and peanuts (15.5-20.0 q/ha) municipal waste water. Lettuce, celery, cauliflower and broccoli have yielded better in reclaimed domestic waste water (Burau *et al.*, 1987).

Nagaraja and Krishnamurthy (1988) reported that sewage water irrigation plus recommended fertilizers resulted in increased grain and straw yields of rice followed by sewage alone and well water plus fertilizer. Sewage effluent (having BOD 500-1000 mg/l) recorded higher crop yields than water plus NPK fertilizer (Nashikkar and Shinde, 1988). Both waste water and potable water plus commercial fertilizer produced similar yields of sorghum, maize and sunflower (Monte and Sousa, 1992).

Burman (1994) observed that growing of pulses and oilseeds crops in polluted soil had adverse effect on the growth and yield attributes. Singh *et al.* (1995) recorded higher fodder yields of maize and sorghum due to treated sewage water irrigation than tube well water.

Fodder sorghum, maize and cowpea yield were increased under sewage + fertilizer application compared to fertilizer application alone (Singh and Rana, 1995). Treated effluent increased the yield of wheat (Hussain *et al.*, 1996).

Salakinkop (1999) emphasised the importance of sewage irrigation in saving 25 per cent cost on fertilizer. Application of 75 per cent RDF and 100 per cent RDF to sewage irrigated land under sewage irrigation

resulted in higher but similar wheat grain and straw yield over other interactions. The sewage irrigated land recorded significantly higher grain (43.7 q/ha) and straw (54.6 q/ha) yield than bore well irrigated land. It also recorded higher growth rate interms of CGR, RGR, NAR and dry matter and yield attributes. Sources of irrigation differed significantly producing higher grain yield in sewage irrigation (41.9 q/ha) than alternate irrigation (39 q/ha) compared to bore well irrigation (35.5 q/ha). Straw yield also followed the same trend recording 57.7, 50.6 and 46.8 q per ha in sewage, alternate and borewell water irrigation, respectively. Further, nutrient concentration in crop in sewage irrigated land were significantly higher than bore well irrigated land.

2.8.2 Quality aspects of produce

There was no degradation of sugarcane quality interms of recovery percentage, brix or purity due to sewage irrigation (Talati, 1950). On the contrary, Buren and Ekeran (1975) noticed that cane juice quality was affected as a result of sewage irrigation. Barley, wheat and oat have produced high protein in grain in sewage irrigated fields, but digestable nutrient contents in grains were not affected (Day *et al.*, 1962). Also barley grain yield, per cent N, malt digestable power, kernel weight, kernel size and malt extract percentage were higher in sewage land (Day *et al.*, 1963).

Wheat grain produced more protein, alanine, histidine, isoleucine and proline in sewage irrigation grains produced in well water plus suggested amount of N, P and K (Day *et al.*, 1975). Marten *et al.* (1980) reported high protein yield of red canary grass but less digestable dry matter compared to maize in sewage irrigation. Quality of cotton lint was unaffected but lowest percentage was noticed (Bielorai *et al.*, 1984).

Johns and McConchie (1994) reported secondary treated effluent application was unlikely to cause any problem to banana plant chemistry and quality. However plant had higher amount of nutrients. Butorac *et al.* (1995) noticed increased sugar yield of sugar beet due to sewage water application.

Quality of crops in terms of protein, gluten improved due to sewage water application and there was no accumulation of heavy metals (Cr, Ni, Pb and Cd) in plant parts above the threshold limit (Salakinkop, 1999).

Material and Methods

III. MATERIAL AND METHODS

The details of the material used and techniques adopted in the study of "Agronomic investigation on use of distillery effluent on the performance of *rabi* maize and wheat" conducted during two consecutive *rabi* seasons of 1999-2000 and 2000-2001 on farmer's field near Sri Lakshmi Narayana Distillery Unit, Garag are presented in this chapter.

3.1 Location of the experimental site

Sri Lakshmi Narayana Distillery Unit, Garag which is about 8 km away from Main Research Station, University of Agricultural Sciences, Dharwad having a latitude of 15°26' N, longitude of 75°07'E at an altitude of 678 m above mean sea level and it falls under Northern Transitional Zone (Zone No.8) of Karnataka state.

3.2 Soil characteristics

The site selected was not irrigated with effluent prior to the initiation of the experiment and the experiment at Garag was selected so as to facilitate effluent availability from the factory conveniently. The texture of the soil was sandy loam. Before the initiation of the experiment, composite soil samples from experimental sites were collected from 0-15 cm depth. Soil samples were air dried, powdered and sieved through 2 mm sieve and were analysed for physico-chemical properties (Table 1).

3.3 Climatic condition

Field experiments were conducted during *rabi* 1999-2000 and 2000-2001. As the meteorological observatory was not existed at experimental station, climatic data were obtained from the nearest observatory of Main Research Station, Dharwad. The Main Research

Table 1. Physico-chemical properties of soil of experimental site at Garag

Sl. No.	Particulars	Value (0-15 cm)	Method adopted
I.	Physical properties		
A.	Mechanical composition		
1.	Sand (%)	60.10	International pipette method (Piper, 1966)
2.	Silt (%)	29.30	
3.	Clay (%)	9.90	
4.	Textural class	Sandy loam	
5.	Bulk density (Mg/m^3)	1.50	Core sampler method (Piper, 1966)
II.	Chemical properties		
1.	Soil reaction (pH)	6.90	pH meter (Piper, 1966)
2.	Electrical conductivity (dSm^{-1})	0.49	Electrical Conductivity Bridge (Jackson, 1967)
3.	Organic carbon (%)	0.48	Walkley and Black's wet oxidation method (Jackson, 1967)
4.	Available nitrogen (kg/ha)	230	Alkaline permanganate method (Subbaiah and Asija, 1956)
5.	Available phosphorus (kg/ha)	30	Olsen's method (Jackson, 1973)
6.	Available potassium (kg/ha)	395.50	Flame photometer (Jackson, 1973)
7.	Exchangeable calcium (meq/100 g)	2.70	Versanate titration
8.	Exchangeable magnesium (meq/100 g)	1.30	
9.	DTPA extractable Zn (ppm)	2.10	DTPA extractant method (Lindsay and Norwell, 1978)
10.	DTPA extractable Cu (ppm)	1.80	
11.	DTPA extractable Fe (ppm)	5	
12.	DTPA extractable Mn (ppm)	9	

Station, receives mean annual rainfall of 797.97 mm which is fairly distributed from April to December. Meteorological data for 1999-2000 and 2000-2001 and the average of 48 years from 1950-1998 as recorded at Meteorological Observatory, Main Research Station, University of Agricultural Sciences, Dharwad is furnished in Table 2 and depicted in Fig.1. The minimum and maximum temperatures and relative humidity were higher during cropping season of 1999-2000 as compared to 2000-2001.

3.4 Previous crop in the experimental area

In the experimental area, a general crop of maize was grown during *kharif* season.

3.5 Experimental details

Four experiments were conducted during two consecutive *rabi* seasons of 1999-2000 and 2000-2001 in a fixed site. The details of experiments undertaken are outlined below.

3.5.1 Experiment 1 : Studies on use of distillery effluent (Solid and Liquid effluents) as a source of nitrogen on the performance of *rabi* maize

Nitrogen substitution levels

S₁ - 100 per cent nitrogen substitution through liquid effluent

S₂ - 100 per cent nitrogen substitution through solid effluent

S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent

S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic

Table 2. Meteorological data for the experimental years 1999-2000, 2000-2001 and average of past 48 years (1950-1998) recorded at the meteorological observatory of Main Research Station, University of Agricultural Sciences, Dharwad, Karnataka

Month	Rainfall (mm)			Temperature (°C)				Relative humidity (%)		
	1999-2000	2000-01	1950-98	Mean maximum		Mean minimum		1999-2000	2000-01	1950-98
				1999-2000	2000-01	1950-98	1999-2000			
April	14.70	44.10	49.51	36.60	37.30	37.09	21.10	65	57	79.10
May	32.80	45.40	87.62	32.20	33.90	36.75	21.30	75	67	57.10
June	71.80	50.70	112.61	28.00	29.00	29.47	21.00	85	79	81.77
July	113.90	125.20	156.03	26.47	26.80	27.05	20.80	89	81	88.37
August	19.70	50.41	102.37	27.10	27.20	27.10	21.40	85	81	86.83
September	8.80	13.21	104.13	28.37	29.00	28.75	20.00	83	76	83.24
October	161.10	88.30	136.62	28.90	29.50	30.17	19.80	79	77	76.26
November	0.00	0.00	35.04	30.40	29.60	29.37	16.90	59	63	68.44
December	0.00	3.00	6.08	28.90	28.30	29.17	13.40	51	58	64.69
January	0.00	0.00	0.11	30.60	28.92	29.13	15.10	48	44	68.88
February	0.00	0.00	0.00	32.20	31.02	34.76	15.70	52	41	50.82
March	0.00	0.00	7.77	35.20	35.09	35.76	18.50	46	38	56.48
Total	422.80	421.32	797.97							

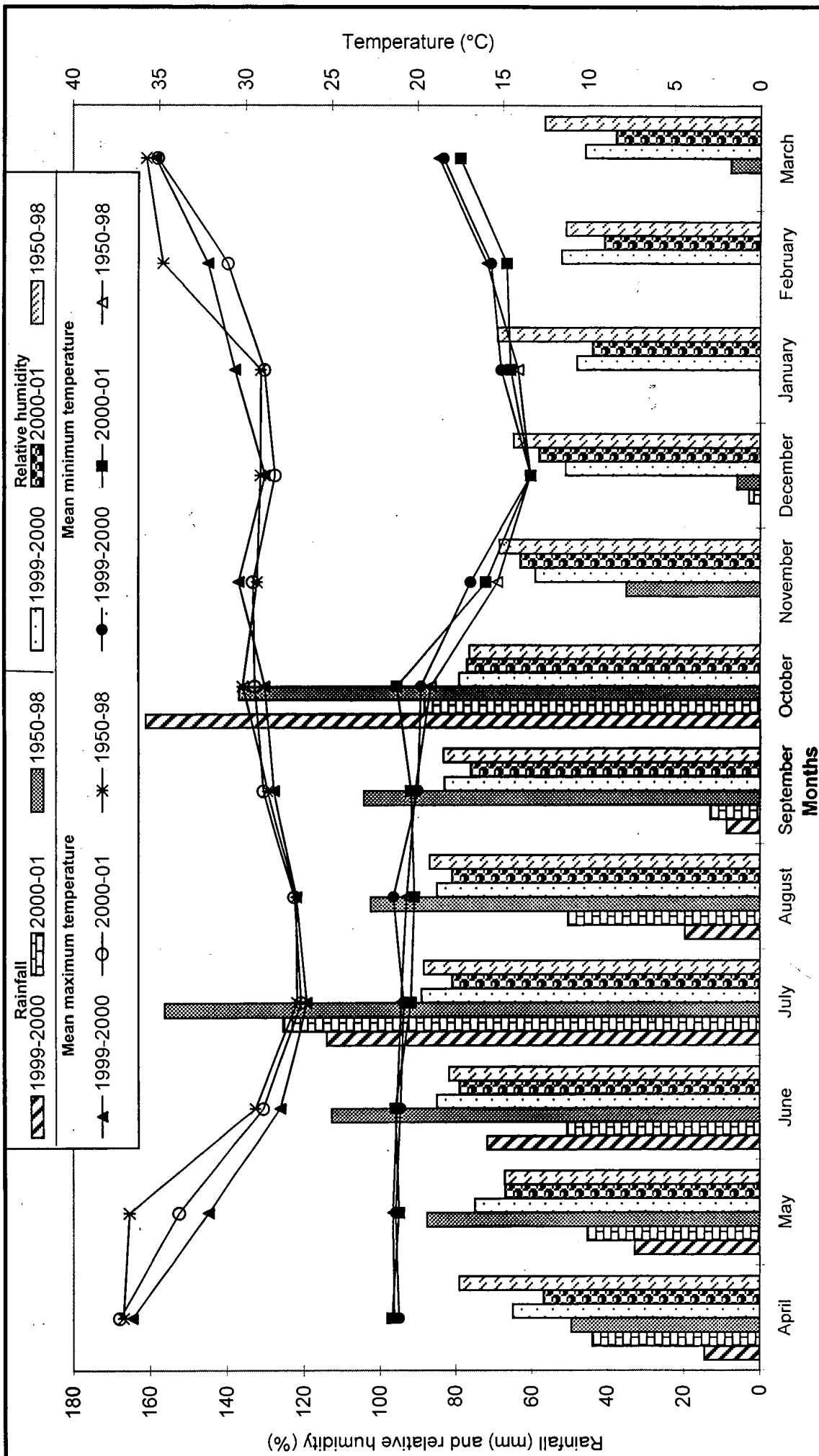


Fig.1. Meteorological data for the experimental years 1999-2000, 2000-2001 and average of past 48 years (1950-1998) recorded at the Meteorological Observatory of Main Research Station, University of Agricultural Sciences, Dharwad, Karnataka

S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic

S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic

S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic

S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent

S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent

S₁₀ - 100% nitrogen through inorganic (150:75:37.5 kg N:P₂O₅:K₂O/ha).

3.5.1.1 Design and layout

The experiment was laid out in a randomized complete block design with three replications. The plan of layout adopted is depicted in Fig.2.

3.5.1.2 Plot size

Gross : 4.8 m x 3.0 m

Net : 2.4 m x 1.8 m.

3.5.2 Experiment 2 : Studies on use of distillery effluent (Solid and Liquid effluents) as a source of nitrogen on the performance of wheat

Nitrogen substitution levels

S₁ - 100 per cent nitrogen substitution through liquid effluent

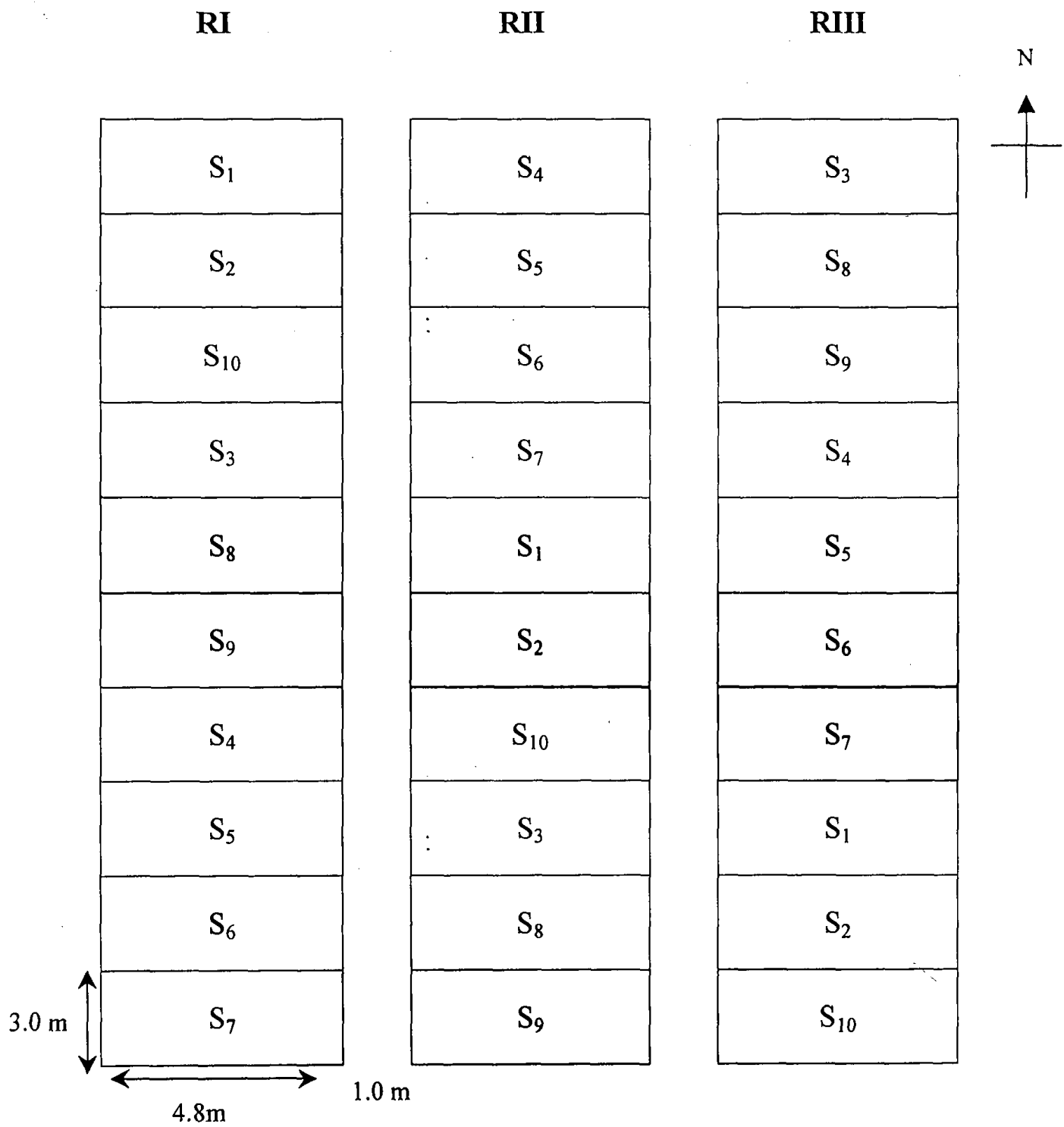


Fig. 2. Plan of layout of experiment 1

- S₂ - 100 per cent nitrogen substitution through solid effluent
- S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent
- S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic
- S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic
- S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic
- S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic
- S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent
- S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent
- S₁₀ - 100% nitrogen through inorganic (100:75:50 kg N:P₂O₅:K₂O/ha).

3.5.2.1 Design and layout

The experiment was laid out in a randomized complete block design with three replications. The plan of layout adopted is depicted in Fig.3.

3.5.2.2 Plot size

Gross : 4.5 m x 3.0 m

Net : 2.7 m x 1.8 m.

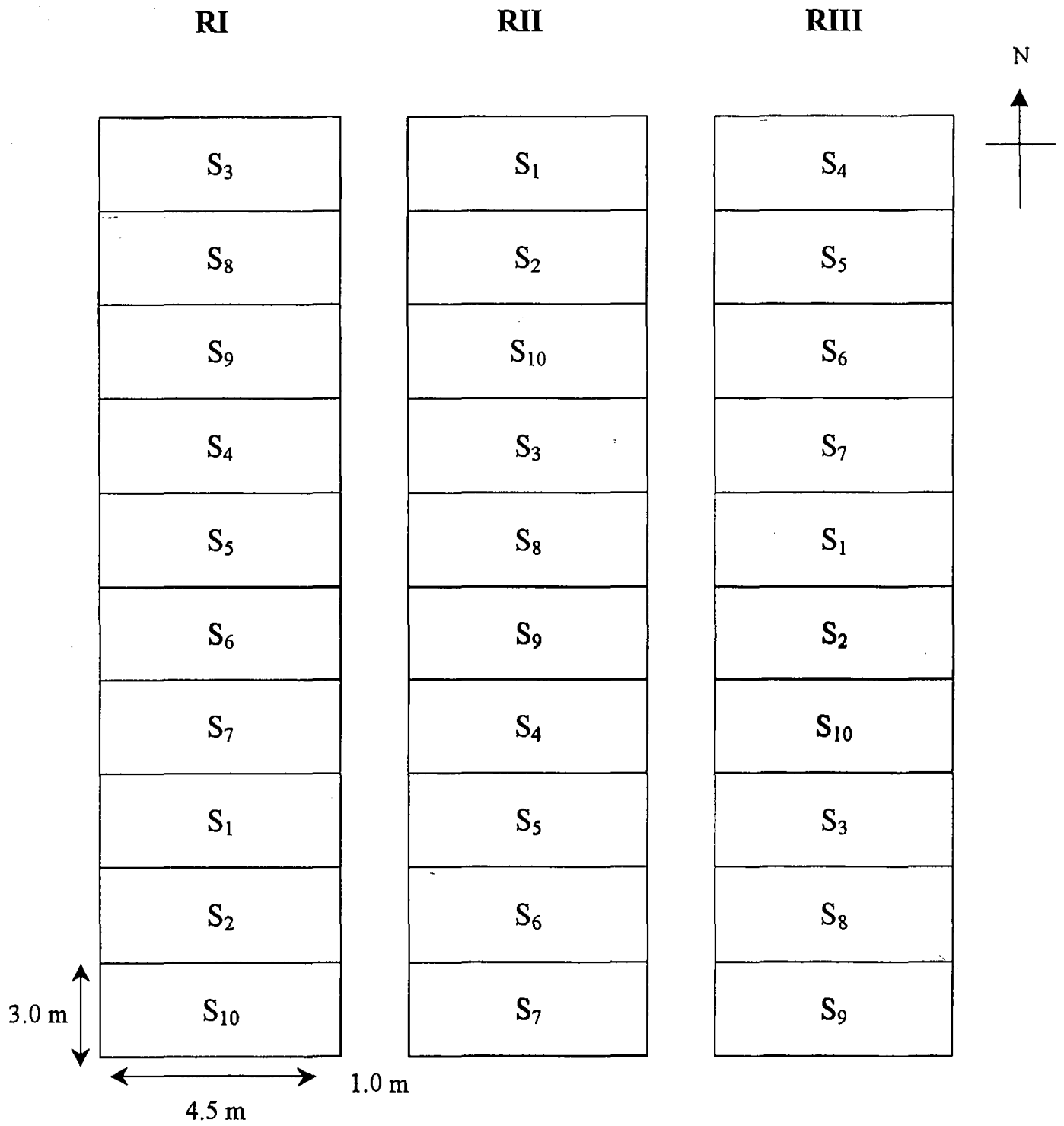


Fig. 3. Plan of layout of experiment 2

Note : Quantity of liquid and solid effluents substitution based on nitrogen content.

Effluent	Crop	Recommended dose of nitrogen (RDN/ha)	Effluent/ha
Liquid	Maize	150 kg/ha	78,947 litres
	Wheat	100 kg/ha	52,631 litres
Solid	Maize	150 kg/ha	30 tonnes
	Wheat	100 kg/ha	20 tonnes

The composition of both solid and liquid distillery effluents is presented in Table 3.

3.5.3 Experiment 3 : Studies on the performance of *rabi* maize against graded dilution of liquid distillery effluent as a source of irrigation

Dilution levels

D₁ - 1:5 (liquid effluent : good water)

D₂ - 1:10 (liquid effluent:good water)

D₃ - 1:25 (liquid effluent: good water)

D₄ - 1:50 (liquid effluent:good water)

D₅ - Undiluted liquid effluent

D₆ - Good water.

3.5.3.1 Design and layout

The experiment was laid out in a randomized complete block design with four replications. The plan of layout adopted is depicted in Fig.4.

3.5.3.2 Plot size

Gross : 4.8 m x 3.0 m

Net : 2.4 m x 1.8 m

Table 3. Characteristics and composition of liquid distillery effluent, solid distillery effluent and borewell water

Parameters	Liquid distillery effluent	Solid distillery effluent	Borewell water
Colour	Dark brown	Brown	-
Odour	Unpleasant	Nil	-
pH	7.8	7.3	7.6
Electrical conductivity (dSm^{-1})	20.8	5.77	0.90
Organic carbon (%)	0.8	1.26	-
Total dissolved solids (mg/litre)	14635	-	-
Total suspended solids (mg/litre)	3800	-	-
BOD (mg/litre)	4620	-	-
COD (mg/litre)	26000	-	-
Nitrogen (%)	0.19	0.5	Trace
Total phosphorus (ppm)	6	84	Trace
Potassium (ppm)	5354	4995	Trace
Total calcium (mg /l)	100	200	1.80
Total magnesium (mg/l)	120	280	4.90
Sulphite (mg/l)	4.20	1.50	1.01
Chloride (mg/l)	14.40	7.01	4.50
Sodium (mg/l)	20	12	6.50
Zinc (mg/l)	6	15	Trace
Copper (mg/l)	3	5	Trace
Iron (mg/l)	38	40	Trace
Manganese (mg/l)	2	4	Trace
Boron (mg/l)	0.4	0.32	Trace
Carbonates (mg/l)	Nil	Nil	Trace
Bicarbonates (mg/l)	150	Nil	10

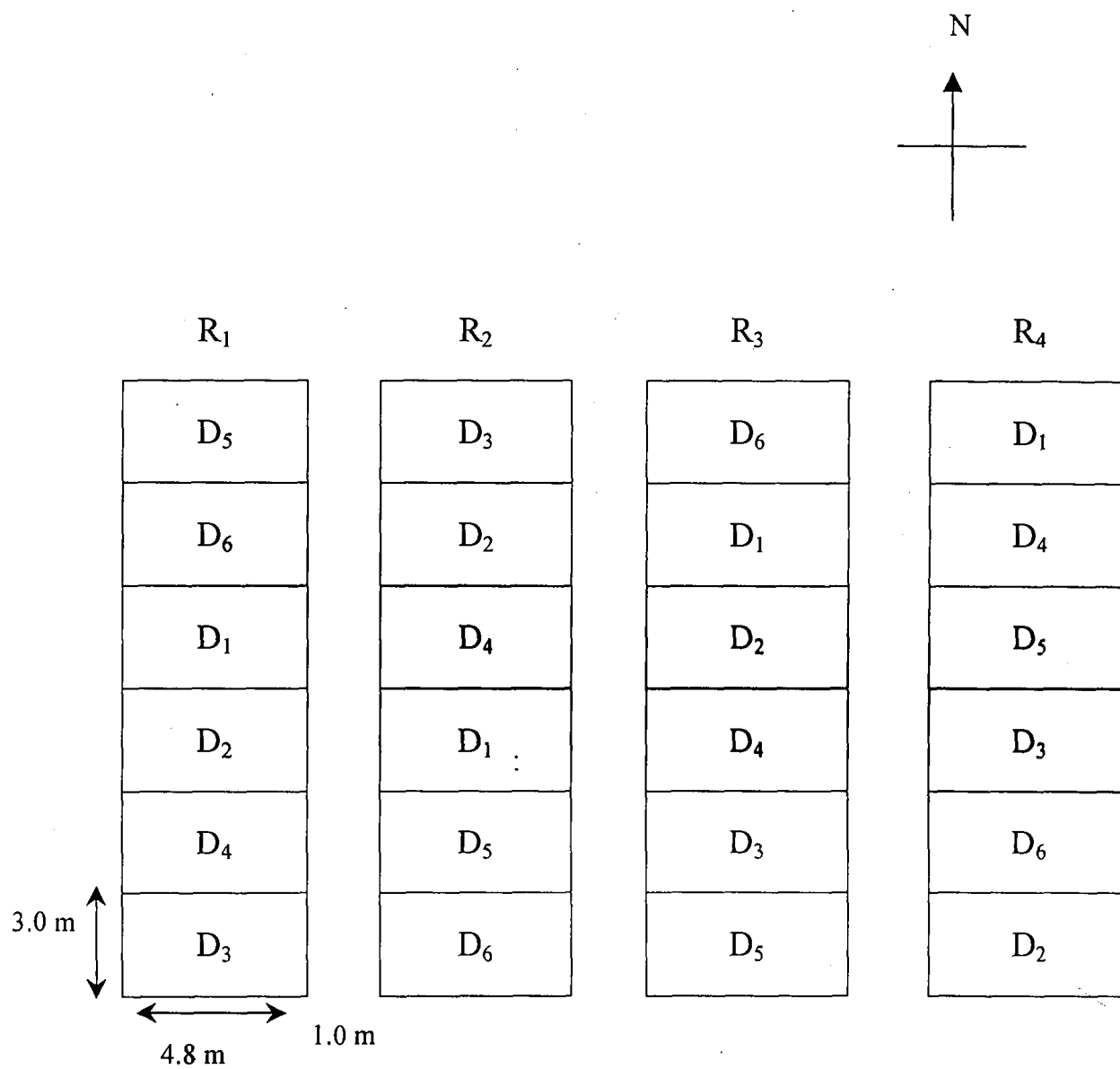


Fig. 4. Plan of layout of experiment 3

3.5.4 Experiment 4 : Studies on the performance of wheat against graded dilution of liquid distillery effluent as a source of irrigation

Dilution levels

- D₁ - 1:5 (liquid effluent : good water)
- D₂ - 1:10 (liquid effluent:good water)
- D₃ - 1:25 (liquid effluent: good water)
- D₄ - 1:50 (liquid effluent:good water)
- D₅ - Undiluted liquid effluent
- D₆ - Good water.

3.5.4.1 Design and layout

The experiment was laid out in a randomized complete block design with four replications. The plan of layout adopted is depicted in Fig.5.

3.5.4.2 Plot size

- Gross : 4.5 m x 3.0 m
- Net : 2.7 m x 1.8 m

3.6 Cultural practices

The details regarding various cultural operations carried out during the course of the investigation are furnished here under.

3.6.1 Land preparation

The land was ploughed once with tractor drawn mould board plough and brought to a fine tilth by passing cultivator twice and harrowing. The leveler was used to level the land. The experimental area was laid out as per the plan with bunds on four sides of each plot. Weeds were removed and finally plots were leveled. Channels were opened to facilitate irrigation.

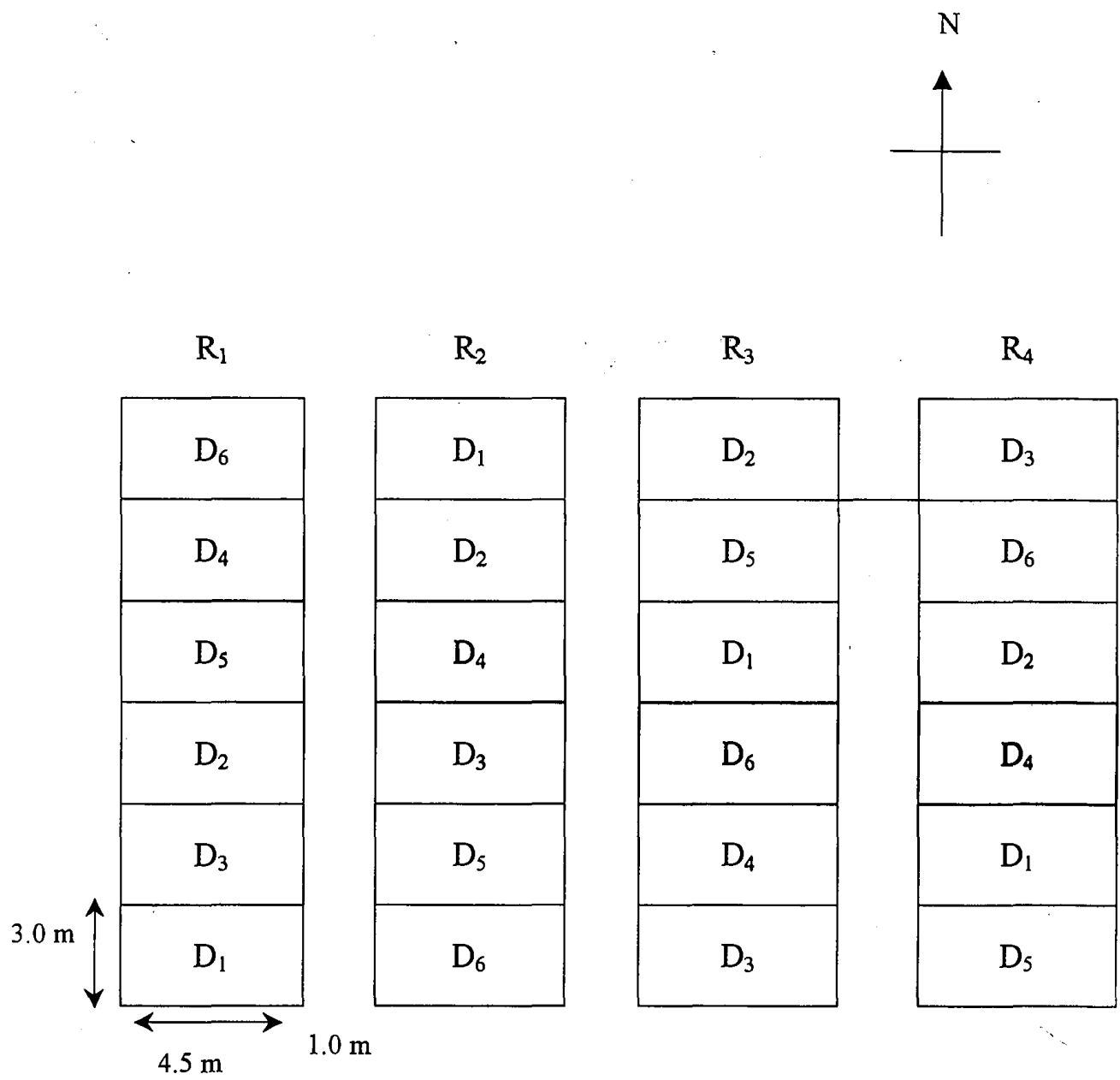


Fig. 5. Plan of layout of experiment 4

3.6.2 Distillery effluents and fertilizer application

In experiments 1 and 2, the required quantity of recommended nitrogen dose (RND) through solid and liquid distillery effluents were calculated as per the treatment details and applied uniformly seven days before sowing on the surface and mixed into the soil. The plots were slightly irrigated further. The remaining RDN as per the treatment and full dose of recommended dose of phosphorus and potassium were applied in the form of urea, single super phosphate and muriate of potash, respectively. Whereas in experiments 3 and 4, the recommended dose of phosphorus, potassium and 50 per cent of RDN was applied at the time of sowing and the remaining 50 per cent of RDN was top dressed at 30 days after sowing for both crops.

3.6.3 Seeds and sowing

Both maize and wheat were sown in second week of November 1999-2000 and 2000-2001. The wheat seeds (DWR-162) were sown at the spacing of 22.5 cm between rows, while maize seeds (DMH-1) were sown at the spacing of 60 cm between rows and 30 cm within the rows in both the experiments. Two weeks after sowing, seedlings were thinned to maintain optimum population in maize crop.

3.6.4 Irrigation

In experiments 1 and 2, irrigation water from borewell was applied before and after sowing to ensure good germination and crop stand. Whereas in experiments 3 and 4, a sintex tank of 15,000 litre capacity was installed by the side of the plot to facilitate uniform mixing of liquid distillery effluent with good water. Adequate irrigations as per the treatment details were applied at an interval of 10-12 days so as to

maintain adequate soil moisture in the root zone. Totally maize crop received 10 while wheat received 8 irrigations.

3.6.5 After care

Hand weeding was carried out twice for both crops coupled with intercultivation once to keep field free from weeds. In maize crop, earthing up was carried out at 30 days after sowing.

3.6.6 Harvesting

Both the crops were harvested after they attained maturity. The border rows were harvested at first leaving the net plot area. The ears in wheat as well as cobs in maize in the net plots were threshed and shelled to separate grains and weight was recorded. After 15 days of sun drying, the dry weight of wheat straw and maize stover was recorded.

3.7 Collection of experimental data

3.7.1 Observations pertaining to *rabi* maize

3.7.1.1 Growth parameters

In order to understand the growth and development of the crop, observations on growth parameters were made by randomly selecting five plants from second row of each plot for destructive sampling and all the growth parameters were recorded.

3.7.1.1.1 Plant height

The height of the five plants was measured in centimeter (cm) from the base of the plant to the base of the fully opened top leaf until cob emergence, after which at 90 days after sowing (DAS) and harvest plant height was measured from the base of the plant to the collar of flag leaf.

3.7.1.1.2 Number of green leaves

Total number of fully opened green leaves produced were counted in five plants at 30, 60, 90 DAS and at harvest and their average was taken as number of green leaves per plant.

3.7.1.1.3 Leaf area per plant

The length and width of the fully opened leaves were measured from five plants per plot. Leaf area was then calculated as $L \times W \times K$, where L = leaf length, W = leaf width and K = constant (0.75). The average was recorded as leaf area per plant and was expressed in dm^2 .

3.7.1.1.4 Total dry matter production and accumulation in different plant parts

The five plants which were selected for growth observations were also used to record the total dry matter production at 30, 60, 90 DAS and at harvest. These samples were oven dried at 65 to 70°C to constant dry weight. Dry weight was recorded separately at each stage for calculating dry matter accumulation in different parts and total dry matter production were expressed in grams per plant.

3.7.1.1.5 Days to 50 per cent tasseling

The number of days from sowing to tassel emergence in 50 per cent of plants within the net plot was recorded as days to 50 per cent tasseling.

3.7.1.2 Physiological studies

3.7.1.2.1 Leaf area index (LAI)

Leaf area index is defined as leaf area (assimilatory source) per unit land area. It was calculated by dividing the leaf area per plant by the land area occupied by a single plant (Watson, 1952).

$$LAI = \frac{\text{Leaf area per plant in cm}^2}{\text{Land area per plant in cm}^2}$$

3.7.1.2.2 Leaf area duration (LAD)

Leaf area duration is an integral of leaf area index over the growth period (Watson, 1952) and was worked out by using the formula of Power *et al.* (1967) and expressed in days.

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

Where, LAI_1 and LAI_2 are periodical observations on leaf area index at an interval of time t_1 and t_2 , respectively.

3.7.1.3 Yield and yield parameters

The cobs from the five randomly selected plants in net plot at the time of harvest were used and the following observations on yield parameters were recorded.

3.7.1.3.1 Cob length

Cob length of five randomly selected cobs was measured and the average was recorded as cob length in cm.

3.7.1.3.2 Cob girth

The circumference measured at the centre of five randomly selected cobs were recorded as cob girth and expressed in cm. Cob girth of five randomly selected cobs were measured and the average was recorded as cob girth in cm.

3.7.1.3.3 Weight per cob

The cobs were air dried and then oven dried and their dry weight was recorded. Their average weight per cob was expressed in g.

3.7.1.3.4 Number of grains per cob

The number of grains per cob was worked out by counting the total number of grains from all the observational cobs and dividing them by number of cobs.

3.7.1.3.5 Grain weight per cob

The seeds from all the five observational cobs were separated, weighed and the average value was expressed in g per cob.

3.7.1.3.6 Test weight

Grain samples collected from the net plot grain yield were used for recording 100 seed weight and was expressed in g.

3.7.1.3.7 Grain yield

At physiological maturity, plants from each net plot were harvested and cobs were separated, air dried, shelled, cleaned and weighed. Grain yield per hectare was worked out and expressed in q per ha.

3.7.1.3.8 Stover yield

Stover yield was recorded after complete sun drying of the stalk from each net plot and expressed in q per ha.

3.7.1.3.9 Harvest index

Harvest index is defined as the ratio of economic yield to total biological yield (Donald, 1962). It was worked out by using the formula as given below.

$$\text{Harvest index} = \frac{\text{Economic yield (q/ha)}}{\text{Total biological yield (q/ha)}}$$

3.7.1.4 Quality parameters

3.7.1.4.1 Protein content

The nitrogen percentage in maize seeds was estimated by modified Microkjeldhal's method (Jackson, 1973). The protein content was calculated by multiplying the nitrogen percentage with factor 6.25 and expressed in percentage (Raghuramulu *et al.*, 1983).

3.7.1.4.2 Reducing sugar

Reducing sugar was estimated by Somogyi method (Nelson, 1944) and expressed in percentage.

3.7.1.4.3 Starch

One hundred milligrams of finely powdered grain sample was homogenized in hot 80 per cent ethanol to extract sugars. The residue was retained after centrifuging and washing repeatedly (3 times) with 80 per cent hot ethanol till the washings gave no colour with anthrone reagent. To the dried residue, 5.0 ml of water and 6.5 ml of 52 per cent perchloric acid was added. The residue was extracted for 20 minutes and supernatant was saved after centrifuging. The procedure was repeated three times with fresh perchloric acid. The volume was determined by anthrone reagent as per the procedure outlined by Sadasivam and Manikam (1992).

3.7.2 Observations pertaining to wheat

3.7.2.1 Growth parameters

Since the wheat crop was harvested in both the years at 105-107 days after sowing, only three observations were recorded at 30 days interval i.e. 30, 60 and 90 DAS.

3.7.2.1.1 Plant sampling and the dry matter accumulation

The plant samples were collected to determine the total dry matter production and its partitioning into leaf and stem at 30 DAS while, into stem, leaf and ear at 60 and 90 DAS. Plant samples were collected from second row on either side of the plot to a row length of one metre each time.

After sampling, the plant parts were separated and oven dried at 80°C to a constant weight to determine the total dry matter. The data were expressed on per metre row basis in g per metre row length.

3.7.2.1.2 Plant height

The plant height of the ten randomly selected plants in a metre row length was measured from the base of the plant to the tip of longest leaves at 30 DAS and from base of plant to the base of the earhead at 60 and 90 DAS and expressed in cm.

3.7.2.1.3 Number of productive tillers

The plant samples per meter row length collected randomly for dry matter production were used for recording the number of productive tillers at maturity.

3.7.2.1.4 Days to 50 per cent heading

The number of days taken from sowing to heading in 50 per cent of plants within the net plot was recorded as days to 50 per cent heading.

3.7.2.2 Physiological studies

3.7.2.2.1 Leaf area index (LAI)

The LAI per m² was calculated by using the formula suggested by Sestak *et al.* (1971).

$$LAI = \frac{\text{Leaf area per m}^2}{\text{Land area per m}^2}$$

3.7.2.2.2 Leaf area duration (LAD)

The LAD is an integral of leaf area index over the growth period. It was worked out using the formula of Power *et al.* (1967) and expressed in days

$$LAD = \frac{LAI_1 + LAI_2}{2} \times (t_2 - t_1)$$

Where,

LAI₁ and LAI₂ are periodical observations on leaf area index at an interval of time t₁ and t₂, respectively.

3.7.2.3 Yield and yield parameters

3.7.2.3.1 Ear length and weight

Ten ears were randomly collected from each plot and length was measured from base to tip of the ear excluding awns and was expressed in cm. While, the weight of these ears was recorded and expressed in g.

3.7.2.3.2 Number of grains per ear

The above mentioned ten ears from each plot were threshed and the grains were counted and the average number of grains per ear was worked out.

3.7.2.3.3 Test weight

Grain samples collected from the net plots were used for recording 1000 grain weight and was expressed in g.

3.7.2.3.4 Grain and straw yield

The total biomass yield for each plot was recorded. After threshing grains were separated, cleaned and weighed. Straw yield was worked out

by subtracting respective total grain weight from the total biomass. Later the plot yield was converted into q per ha.

3.7.2.3.5 Harvest index (HI)

From the yield of grain and straw, the harvest index was calculated by using the formula given by Donald (1962) as follows.

$$HI = \frac{\text{Grain yield (q/ha)}}{\text{Grain + straw yield (q/ha)}}$$

3.7.2.4 Quality parameters

3.7.2.4.1 Protein estimation

The total nitrogen in grains was estimated by Microkjeldhal method (Jackson, 1967). The protein content in grains was calculated by multiplying the nitrogen content of grains with a conversion factor 6.25 (Raghuramulu *et al.*, 1983) and expressed in percentage.

3.7.2.4.2 Sedimentation value

Six gram whole meal was mixed with 50 ml distilled water and shook rapidly for 15 seconds. Fifty ml sodium decocyl sulphate containing lactic acid was added and shook rapidly for 15 seconds. This was repeated thrice. Then cylinder was allowed to stand exactly for 20 minutes at room temperature and the volume of the sediment was recorded (Mishra and Gupta, 1995).

3.7.2.4.3 Gluten content

Twenty gram of whole meal was kneaded into a normal dough with requisite amount of water. The dough was transferred into muslin cloth and allowed the dough for 30-40 minutes at room temperature in a

beaker containing water. Dough mass was washed by pressing with finger under tap water. The dough was taken from cloth in hand and washed directly under running tap water and tested with iodine solution to ensure complete removal of starch from it. The wet and dry gluten weights were recorded before and after drying in an oven at 105°C (Austin and Ram, 1971).

3.8 Plant analysis

3.8.1 Collection and preparation of plant samples

Plant samples were collected at random from the each treatment, air dried and then they were placed in hot air oven at 60°C for 18 hours, the samples were powdered in willey mill and were used for analysis.

3.8.2 N, P, K, Zn, Cu, Fe and Mn content of maize and wheat

Plant samples were analysed for N, P and K contents at anthesis and harvest as per the following methods.

The N content was estimated by Microkjeldahl method (Jackson, 1973) and expressed in percentage.

The P content of triacid digestion extract was determined by Vanadomolybdo phosphoric yellow colour method using spectrophotometer (Jackson, 1973) and expressed in percentage.

The extract from triacid digestion was used for estimation of potassium by Flame photometry as outlined by Jackson (1973) and expressed in percentage.

At harvest Zn, Cu and Mn were estimated in the aliquot of plant digest by using atomic absorption spectrophotometer (Shimadzu AA-630-11).

Fe content was determined colorimetrically by Orthophenanthroline as described by Jackson, (1973).

3.8.3 Total uptake of N, P, K, Zn, Cu, Fe and Mn at harvest

The removal of N, P, K, Zn, Cu, Mn and Fe by crops was calculated for each treatment separately using formula.

$$\text{Nutrient uptake (kg/ ha)} = \frac{\% \text{ of nutrient concentration}}{100} \times \text{biomass (kg/ha)}$$

3.9 Soil analysis

Initial representative soil samples were collected from a depth of 0-15 cm from entire plot according to standard method. Sample was air dried, powdered, sieved through 2 mm sieve and used for analysis of soil.

Soil samples after harvest of the crops were collected from the root zone at four points from each plot and composite samples were prepared for chemical analysis.

3.9.1 Determination of physical property of soil

3.9.1.1 Bulk density

Bulk density of soil was calculated from their mass and volume using core sampler method (Black, 1965) and was expressed in Mg per m³.

3.9.2 Determination of chemical properties of soil

3.9.2.1 Soil reaction

The soil reaction (pH) was determined in 1:2.5, soil water suspension by glass electrode using digital pH meter (Piper, 1966).

3.9.2.2 Electrical conductivity

Electrical conductivity (EC) of 1:2.5 soil water suspension was determined by using conductivity bridge (Jackson, 1967).

3.9.2.3 Organic carbon

Organic carbon (OC) was estimated according to Walkley and Black's wet oxidation method (Jackson, 1967).

3.9.2.4 Determination of nutrient content in soil

3.9.2.4.1 Available nitrogen

Available nitrogen was determined by alkaline permanganate method of Subbaiah and Asija (1956).

3.9.2.4.2 Available phosphorus

Available phosphorus was determined by Olsen's method outlined by Jackson (1973), using spectrophotometer (660 nm wave length).

3.9.2.4.3 Available potassium

Available potassium was estimated flame photometrically from the extract of neutral, normal ammonium acetate (Jackson, 1973).

3.9.2.4.4 DTPA extractable zinc, copper, iron and manganese

The extracting solution used for this purpose consisted of 0.005 M DTPA (Diethylene triamine penta acetic acid), 0.01 M CaCl_2 and 0.1M TEA (Triethanol amine) buffered at pH 7.3 (Lindsay and Norwell, 1978). The concentration of these nutrients was read in atomic absorption spectrophotometer (Shimadzu AA-630-11).

3.10 Economics

The prices in rupees of the inputs at the prevailing time of their use was considered for working out the cost of cultivation.

Net return (Rs./ha) = Gross return (Rs./ha) - Cost of cultivation (Rs./ha).

$$\text{Benefit:cost ratio} = \frac{\text{Net return (Rs./ha)}}{\text{Cost of cultivation (Rs./ha)}}$$

3.11 Statistical analysis and interpretation of data

The data collected from the experiment at different growth stages were subjected to statistical analysis as described by Gomez and Gomez (1984). The level of significance used in 'F' and 't' tests was P=0.05. Critical difference values were calculated wherever, the 'F' test was significant.

3.12 Correlation studies

Correlation studies were made between yield and some important growth, yield, quality and soil parameters as per the procedures outlined by Gomez and Gomez (1984) (Appendix I to IV).

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of the field experiments to study the “Agronomic investigation on use of distillery effluent on the performance of *rabi* maize and wheat” during two consecutive *rabi* seasons of 1999-2000 and 2000-2001 are presented in this chapter. Treatment effects remained almost same and no contrary results were recorded hence only results of pooled analysis of both the years are presented.

4.1 Experiment 1 : Studies on use of distillery effluent (Solid and Liquid effluents) as a source of nitrogen on the performance of *rabi* maize

4.1.1 Growth parameters

4.1.1.1 Plant height (cm) (Table 4)

Plant height of maize increased with an advancement in crop growth. Substitution of nitrogen had shown significant effect on plant height at all growth stages. Significantly higher plant heights of 19.36, 122.86, 203.91 and 212.20 at 30, 60, 90 days after sowing (DAS) and at harvest, respectively at nitrogen substitution level of 50 per cent through solid effluent plus 50 per cent through inorganic source (S₅) but were found on par with nitrogen substitution levels of 25 per cent through solid effluent plus 75 per cent through inorganic source (S₇) and 100 per cent through inorganic source (S₁₀). While significantly lower plant heights of 17.35, 109.68, 181.83 and 188.94 at 30, 60, 90 DAS and at harvest, respectively were recorded at nitrogen substitution level of 25 per cent through solid effluent plus 75 per cent through liquid effluent (S₉) over other nitrogen substitution levels and were found on par with 100 per cent nitrogen substitution through liquid effluent (S₁), 50 per cent nitrogen substitution through liquid effluent plus 50 per cent

Table 4. Plant height (cm) at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	17.26	17.68	17.47	108.53	111.29	109.91	180.32	184.90	182.61	187.56	192.30	189.93
S ₂ – 100% N substitution through solid effluent	17.46	17.85	17.65	111.37	113.98	112.67	185.39	189.71	187.55	192.53	197.03	194.78
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	17.35	17.66	17.50	110.58	112.38	111.48	183.44	186.54	184.99	191.15	194.39	192.77
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	14.81	18.75	18.58	118.30	119.74	119.02	193.95	197.57	195.76	201.62	205.20	203.41
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	17.10	19.62	19.36	121.13	124.59	122.86	201.06	206.76	203.91	209.23	215.17	212.20
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	18.66	18.94	18.80	119.91	121.78	124.84	195.73	198.81	197.27	202.38	205.74	204.06
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	19.12	19.44	19.28	120.84	122.90	121.87	199.82	203.26	201.54	208.08	211.66	209.87
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	17.37	17.89	17.63	111.46	116.05	113.75	183.21	188.81	186.01	190.10	195.92	193.01
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	17.25	17.46	17.35	109.03	110.33	109.68	180.76	182.90	181.83	187.83	190.05	188.94
S ₁₀ – 100% N substitution through inorganic source	19.14	19.28	19.21	121.16	122.12	121.64	200.30	201.92	201.11	208.09	209.80	208.14
S.E.m±	0.35	0.40	0.27	2.63	2.94	1.97	3.10	3.40	2.30	3.21	3.52	2.38
CD at 5%	1.06	1.24	0.79	7.81	8.73	5.65	9.21	10.09	6.60	9.53	10.45	8.56

DAS – Days after sowing

through solid effluent (S₃), 25 per cent nitrogen substitution through liquid effluent plus 75 per cent through solid effluent (S₈) and 100 per cent nitrogen substitution through solid effluent (S₂).

4.1.1.2 Number of leaves (Table 5)

Number of leaves per plant increased upto 60 DAS and thereafter showed declining trend. However, the number of leaves per plant were found non significant at all the stages due to substitution levels of nitrogen through distillery effluents.

4.1.1.3 Leaf area (dm²/plant) (Table 6)

Substitution of nitrogen using distillery effluents had significant influence on leaf area of maize. In general, leaf area was high during tasseling or early silking stage (60 to 75 DAS) and it declined at later stages. Substitution level of S₅ registered significantly higher leaf area at all the stages (6.80, 82.69, 71.73 and 34.93 at 30, 60, 90 DAS and at harvest, respectively) and was found on par with S₇ and S₁₀. Whereas, significantly lowest leaf area was recorded with S₉ (6.09, 74.30, 64.36 and 31.34 at 30, 60, 90 DAS and at harvest, respectively) which was found on par with S₁, S₃, S₈ and S₂.

4.1.1.4 Leaf area index (Table 7)

At all growth stages, substitution of nitrogen by distillery effluents had significant influence on leaf area index (LAI). Among substitution levels, S₅ recorded significantly higher LAI of 0.377, 4.59, 3.98 and 1.94 at 30, 60, 90 DAS and at harvest respectively followed by S₇ and S₁₀ substitution levels. Whereas, the lowest LAI of 0.338 at 30 DAS, 4.12 at 60 DAS and 3.57 at 90 DAS and 1.74 at harvest were recorded at S₉.

Table 5. Number of green leaves at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	6.24	6.31	6.28	13.10	13.35	13.22	11.53	11.68	11.60	4.28	4.36	4.32
S ₂ – 100% N substitution through solid effluent	6.30	6.38	6.34	13.25	13.47	13.36	11.67	11.70	11.68	4.35	4.37	4.36
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	6.28	6.32	6.30	13.20	13.17	13.18	11.65	11.66	11.60	4.28	4.38	4.33
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	6.30	6.58	6.44	13.30	13.46	13.38	11.70	11.70	11.70	4.45	4.47	4.46
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	6.42	6.88	6.65	13.60	13.97	13.78	12.00	12.52	12.26	4.60	4.65	4.62
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	6.35	6.58	6.47	13.50	13.76	13.62	11.80	12.05	11.92	4.45	4.50	4.47
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	6.30	6.70	6.50	13.55	13.53	13.54	11.90	12.30	12.10	4.58	4.60	4.59
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	6.35	6.38	6.36	13.25	13.27	13.26	11.70	11.66	11.68	4.30	4.38	4.33
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	6.28	6.30	6.29	13.15	13.16	13.15	11.45	11.66	11.56	4.25	4.28	4.27
S ₁₀ – 100% N substitution through inorganic source	6.40	6.58	6.49	13.50	13.77	13.63	11.80	12.10	11.95	4.50	4.54	4.52
S.E.m±	0.24	0.22	0.17	0.64	0.70	0.47	0.47	0.50	0.34	0.19	0.18	0.13
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAS – Days after sowing

NS – Non significant

Table 6. Leaf area (dm^2/plant) at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	6.04	6.22	6.13	73.46	75.54	74.50	63.67	65.49	64.58	31.01	31.89	31.45
S ₂ – 100% N substitution through solid effluent	6.12	6.34	6.23	75.58	78.30	76.99	64.46	67.30	65.88	31.40	32.76	32.08
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	6.14	6.19	6.16	74.22	75.48	74.85	64.38	65.49	64.93	31.35	31.89	31.62
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	6.51	6.63	6.57	78.14	79.66	78.90	67.65	68.97	68.31	33.28	34.22	33.75
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	6.70	6.90	6.80	81.53	83.85	82.69	70.72	72.74	71.73	34.44	35.42	34.93
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	6.59	6.68	6.63	78.98	80.22	79.60	68.41	69.49	68.95	33.68	34.20	33.94
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	6.71	6.83	6.77	81.57	82.99	82.28	70.76	71.98	71.37	34.47	35.06	34.76
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	6.14	6.30	6.21	74.31	76.57	75.44	64.47	66.43	65.45	31.38	32.34	31.86
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	6.05	6.13	6.09	73.85	74.76	74.30	63.97	64.75	64.36	31.15	31.53	31.34
S ₁₀ – 100% N substitution through inorganic source	6.72	6.74	6.73	81.58	82.01	81.79	70.77	71.13	70.95	34.46	34.64	34.55
S.E.m±	0.20	0.23	0.15	1.49	1.53	1.07	1.31	1.35	0.95	0.42	0.48	0.32
CD at 5%	0.59	0.68	0.44	4.43	4.54	3.07	3.89	4.01	2.73	1.25	1.42	0.92

DAS – Days after sowing

Table 7. Leaf area index (LAI) at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS				60 DAS				90 DAS				At harvest		
	1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	0.335	0.345	0.340		4.08	4.19	4.13		3.54	3.64	3.59		1.72	1.77	1.74
S ₂ – 100% N substitution through solid effluent	0.340	0.352	0.346		4.19	4.35	4.27		3.58	3.74	3.66		1.74	1.82	1.78
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	0.341	0.344	0.342		4.12	4.93	4.52		3.58	3.64	3.61		1.74	1.77	1.76
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	0.362	0.368	0.365		4.34	4.42	4.38		3.76	3.83	3.79		1.85	1.90	1.87
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	0.372	0.383	0.377		4.53	4.66	4.59		3.93	4.04	3.98		1.91	1.97	1.94
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	0.366	0.371	0.368		4.39	4.56	4.47		3.80	3.86	3.83		1.87	1.90	1.88
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	0.373	0.379	0.376		4.53	4.61	4.57		3.93	3.99	3.96		1.91	1.95	1.93
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	0.341	0.350	0.345		4.13	4.25	4.19		3.58	3.69	3.63		1.74	1.95	1.84
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	0.336	0.340	0.338		4.10	4.15	4.12		3.55	3.60	3.57		1.73	1.75	1.74
S ₁₀ – 100% N substitution through inorganic source	0.373	0.374	0.373		4.53	4.56	4.54		3.93	3.95	3.94		1.91	1.92	1.91
S.E.m±	0.007	0.007	0.005		0.05	0.06	0.01		0.06	0.04	0.03		0.03	0.04	0.02
CD at 5%	0.021	0.021	0.014		0.15	0.18	0.03		0.18	0.11	0.10		0.09	0.12	0.06

DAS – Days after sowing

4.1.1.5 Leaf area duration (Days) (Table 8)

Nitrogen substitution with solid and liquid distillery effluents influenced significantly on leaf area duration (LAD) of maize at all growth stages. Significantly higher LAD (74.58, 128.70 and 88.87 at 30-60 DAS, 60-90 DAS and 90 DAS-harvest, respectively) was recorded with S₅ however it was found on par with S₇ and S₁₀. Whereas, significantly lower LAD was recorded at S₉ at all growth stages (66.94, 115.50 and 79.72 at 30-60 DAS, 60-90 DAS and 90 DAS-harvest, respectively).

4.1.1.6 Dry matter production and its accumulation

4.1.1.6.1 Total dry matter production (g/plant) (Table 9)

There were significant differences on total dry matter (TDM) production per plant at all growth stages due to nitrogen substitution levels. There was progressive increase in TDM production with age of crop. Significantly higher TDM was registered at S₅ at 30, 60, 90 DAS and at harvest (8.19, 78.52, 234.51 and 331.57, respectively) and was found on par with S₇ and S₁₀. Whereas, significantly lower TDM production was recorded at S₉ (7.33, 70.26, 209.90 and 280.82 at 30, 60, 90 DAS and at harvest, respectively) over rest of substitution levels except S₁, S₃, S₈ and S₂.

4.1.1.6.2 Dry matter accumulation in leaves (g/plant) (Table 10)

Dry matter accumulation (DMA) in leaves differed significantly at all growth stages. Substitution level S₅ recorded significantly higher DMA in leaves (5.58, 42.06, 49.02 and 50.45 at 30, 60, 90 DAS and at harvest, respectively) but was found on par with S₇ and S₁₀. While, substitution

Table 8. Leaf area duration (LAD, days) at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30-60 DAS			60-90 DAS			90 DAS-Harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	66.22	68.02	67.12	114.30	117.45	115.87	78.90	81.15	80.02
S ₂ – 100% N substitution through solid effluent	67.95	70.53	69.24	116.56	121.35	118.95	79.80	83.40	81.60
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	66.91	79.11	73.04	115.50	128.56	122.03	79.80	80.25	80.02
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	70.45	71.82	71.17	121.50	123.75	122.62	84.15	85.95	85.05
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	73.53	75.64	74.58	126.90	130.50	128.70	87.60	90.15	88.87
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	71.34	73.96	72.65	122.86	126.30	124.58	85.05	86.40	85.72
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	73.54	74.83	74.18	126.90	129.00	127.95	87.60	89.10	88.35
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	67.06	69.00	68.03	115.65	119.10	117.37	79.80	84.60	82.20
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	66.54	67.35	66.94	114.76	116.25	115.50	79.20	80.25	79.72
S ₁₀ – 100% N substitution through inorganic source	73.55	74.01	73.78	126.90	127.65	127.27	87.60	88.05	87.82
S.E.m±	1.02	1.04	0.73	1.60	1.96	1.26	1.32	1.65	1.05
CD at 5%	3.03	3.09	2.10	4.75	5.82	3.62	3.92	4.90	3.01

DAS – Days after sowing

Table 9. Total dry matter production (g/plant) at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	7.27	7.48	7.37	69.70	71.68	70.69	207.25	213.17	210.21	277.23	289.32	283.27
S ₂ – 100% N substitution through solid effluent	7.37	7.65	7.51	70.47	73.55	72.01	209.49	218.70	214.09	284.34	296.26	290.30
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	7.35	7.47	7.41	70.48	71.68	71.08	209.56	213.12	211.34	281.86	288.48	285.17
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	7.85	8.00	7.92	74.04	75.50	74.47	222.02	226.31	224.16	305.85	316.61	311.23
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	8.07	8.31	8.19	77.40	79.64	78.52	231.21	237.81	234.51	325.03	338.11	331.57
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	7.91	8.03	7.97	74.43	75.61	75.02	222.52	227.24	224.88	311.88	316.63	314.25
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	8.09	8.21	8.15	77.45	78.81	78.13	231.33	235.37	233.35	325.20	332.66	328.93
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	7.36	7.60	7.48	70.55	72.72	71.63	210.76	217.17	213.96	283.50	291.82	287.66
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	7.29	7.37	7.33	69.83	70.69	70.26	208.64	211.16	209.90	279.20	282.44	280.82
S ₁₀ – 100% N substitution through inorganic source	8.09	8.13	8.11	77.48	77.84	77.66	231.42	232.50	231.96	325.38	326.97	326.17
S.Em±	0.16	0.17	0.12	1.40	1.45	1.01	2.76	2.83	1.98	2.80	2.89	2.01
CD at 5%	0.47	0.50	0.34	4.16	4.31	2.89	8.19	8.40	5.68	8.31	8.58	5.77

DAS – Days after sowing

Table 10. Dry matter accumulation in leaf (g/plant) at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	4.95	5.09	5.02	37.34	38.40	37.87	43.51	44.75	44.13	44.78	46.06	45.42
S ₂ – 100% N substitution through solid effluent	5.02	5.24	5.13	37.79	39.47	38.63	44.05	45.99	45.02	45.33	47.34	46.33
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	5.01	5.09	5.05	37.75	38.39	38.07	43.99	44.75	44.37	45.28	46.04	45.66
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	5.35	5.46	5.40	40.20	40.98	40.59	46.67	47.58	47.12	48.23	49.15	48.69
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	5.50	5.66	5.58	41.47	42.65	42.06	48.33	49.71	49.02	49.74	51.16	50.45
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	5.41	5.49	5.45	40.40	41.04	40.72	46.90	47.64	47.27	48.43	49.27	48.85
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	5.51	5.59	5.55	41.48	42.22	41.85	48.36	49.20	48.78	49.77	50.63	50.20
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	5.01	5.17	5.09	37.79	38.95	38.37	44.06	45.40	44.73	45.34	46.72	46.03
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	4.96	5.02	4.99	37.43	37.89	37.66	43.61	44.13	43.87	44.89	45.43	45.16
S ₁₀ – 100% N substitution through inorganic source	5.51	5.53	5.52	41.49	41.71	41.60	48.38	48.60	48.49	44.78	50.02	49.90
S.E.m±	0.13	0.14	0.16	0.66	0.69	0.48	0.78	0.82	0.57	0.58	0.68	0.45
CD at 5%	0.39	0.41	0.46	1.96	2.05	1.37	2.32	2.43	1.63	1.72	2.02	1.28

DAS – Days after sowing.

level S₉ registered significantly lower DMA in leaves at all the stages followed by S₁.

4.1.1.6.3 Dry matter accumulation in stem (g/plant) (Table 11)

Substitution of nitrogen using distillery effluents influenced the DMA in stem significantly at all the growth stages significantly higher DMA in stem was recorded at S₅ (2.61, 36.46, 78.08 and 71.88 at 30, 60, 90 DAS and at harvest, respectively) and was found on par with S₇ and S₁₀. Significantly lowest DMA in stem was recorded at S₉ at all growth stages (2.34, 32.60, 69.86 and 64.34 at 30, 60, 90 DAS and at harvest, respectively).

4.1.1.6.4 Dry matter accumulation in cob (g/plant) (Table 12)

Nitrogen substitution using distillery effluents had significant influence on DMA in cob at both 90 DAS and harvest. Substitution level of S₅, S₇ and S₁₀ registered significantly higher DMA in cob over other substitution levels and these three substitution levels found on par among themselves. However, significantly lowest DMA in cob (91.65 and 167.58 at 90 DAS and harvest, respectively) recorded with S₉ followed by S₁, S₃, S₈ and S₂.

4.1.1.6.5 Dry matter accumulation in tassel (g/plant) (Table 12)

Substitution of nitrogen by distillery effluents significantly influenced the DMA in tassel both at 90 DAS and harvest. Substitution level of S₅ recorded significantly higher DMA in tassel at both stages (5.06 and 4.18 at 90 DAS and harvest respectively) but was found on par with S₇, S₁₀, S₆ and S₄. Significantly lowest DMA in tassel was recorded with S₉ and S₂ which found on par with S₁, S₃, S₈ and S₂.

Table 11 . Dry matter accumulation in stem (g/plant) at different growth stages in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS			60 DAS			90 DAS			At harvest	
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001
S ₁ – 100% N substitution through liquid effluent	2.32	2.38	2.35	32.36	33.28	32.82	69.30	71.28	70.29	63.80	65.62
S ₂ – 100% N substitution through solid effluent	2.35	2.45	2.40	32.68	34.08	33.38	70.16	73.26	71.71	64.59	67.45
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	2.34	2.38	2.36	32.73	33.29	33.01	70.08	71.26	70.67	64.51	65.62
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	2.50	2.54	2.52	33.84	34.52	34.18	73.65	75.07	74.36	67.73	69.05
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	2.57	2.65	2.61	35.93	36.99	36.46	76.98	79.18	78.08	70.87	72.89
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	2.50	2.54	2.52	34.03	34.57	34.30	74.03	75.19	74.61	68.08	61.14
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	2.59	2.62	2.60	35.97	36.59	36.28	77.02	78.36	77.69	70.91	72.15
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	2.35	2.43	2.39	32.76	33.77	33.26	70.17	72.31	71.24	64.60	66.56
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	2.33	2.35	2.34	32.40	32.80	32.60	69.44	70.28	69.86	63.95	64.73
S ₁₀ – 100% N substitution through inorganic source	2.58	2.60	2.59	35.99	36.13	36.06	77.04	77.42	77.23	70.92	71.28
S.E.m±	0.07	0.07	0.05	0.99	1.05	0.72	1.54	1.72	1.16	1.50	1.53
CD at 5%	0.21	0.21	0.14	2.94	3.12	2.07	4.57	5.10	3.33	4.45	4.54

DAS – Days after sowing

Table 12. Dry matter accumulation in cob (g/plant) and tassel (g/plant) at 90 DAS and harvest in *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Dilution level	90 DAS						At harvest					
	Cob			Tassel			Cob			Tassel		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ - 100% N substitution through liquid effluent	89.97	92.53	91.25	4.47	4.61	4.54	164.92	173.82	169.40	3.73	3.82	3.78
S ₂ - 100% N substitution through solid effluent	90.80	94.81	92.80	4.48	4.64	4.56	170.65	177.56	174.10	3.77	3.91	3.84
S ₃ - 50% N substitution through liquid effluent + 50% N substitution through solid effluent	90.96	92.50	91.73	4.53	4.61	4.57	168.32	173.01	170.66	3.75	3.81	3.78
S ₄ - 50% N substitution through liquid effluent + 50% N substitution through inorganic source	96.87	98.73	97.80	4.83	4.93	4.88	190.90	194.34	192.62	3.99	4.07	4.03
S ₅ - 50% N substitution through solid effluent + 50% N substitution through inorganic source	100.92	103.78	102.35	4.98	5.14	5.06	200.30	200.82	205.06	4.12	4.24	4.18
S ₆ - 25% N substitution through liquid effluent + 75% N substitution through inorganic source	96.74	99.48	98.11	4.85	4.93	4.89	191.36	194.15	192.75	4.01	4.07	4.04
S ₇ - 25% N substitution through solid effluent + 75% N substitution through inorganic source	100.97	102.73	101.85	4.98	5.08	5.03	200.40	205.70	203.03	4.12	4.18	4.15
S ₈ - 25% N substitution through liquid effluent + 50% N substitution through solid effluent	91.97	94.78	93.38	4.54	4.68	4.61	169.82	174.68	172.25	3.74	3.86	3.80
S ₉ - 25% N substitution through solid effluent + 75% N substitution through liquid effluent	91.10	92.20	91.65	4.49	4.55	4.52	166.63	168.53	167.58	3.73	3.75	3.74
S ₁₀ - 100% N substitution through inorganic source	101.01	101.47	101.24	4.99	5.01	5.00	200.56	201.52	201.04	4.12	4.15	4.13
S.E.m±	1.91	1.96	1.37	0.14	0.15	0.10	3.40	3.72	2.52	0.13	0.14	0.09
CD at 5%	5.67	5.82	3.93	0.41	0.44	0.29	10.09	11.05	7.23	0.39	0.41	0.27

4.1.1.7 Days to 50 per cent tasseling (Table 13)

Nitrogen substitution through distillery effluent varied significantly with respect to days to 50 per cent tasseling. Nitrogen substitution level of S₅ took significantly lesser days to 50 per cent tasseling (65.70) than other substitution levels however was found on par with S₇, S₁₀, S₆ and S₄. Significantly more number of days to 50 per cent tasseling was recorded with S₉ followed by S₁, S₃, S₈, and S₂.

4.1.2 Yield and yield parameters

4.1.2.1 Cob length (cm) (Table 13)

Significant difference on cob length was noticed with regard to substitution of nitrogen with distillery effluents. Substitution level of S₅ registered significantly lengthier cobs (17.70) as compared to other substitution levels but was found on par with S₇ and S₁₀. Whereas, significantly shortest cob length of 15.85 was recorded with S₉ which was found on par with cob length at S₁, S₃, S₈, and S₂.

4.1.2.2 Cob girth (cm) (Table 13)

The nitrogen substitution levels using distillery effluents brought significant difference on cob diameter. The cob diameter was significantly higher at S₅ (4.96) followed by S₇, S₁₀ and all these found significantly superior over rest of substitution levels. While, significantly the lowest cob girth (4.46) was recorded with S₉.

4.1.2.3 Weight per cob (g) (Table 13)

Weight per cob varied significantly due to variation in nitrogen substitution levels. Significantly higher weight per cob of 195.06 was

Table 13. Days to 50% tasseling, cob length (cm), cob girth (cm) and weight per cob (g) of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Days to 50% tasseling			Cob length (cm)			Cob girth (cm)			Weight per cob		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S1 – 100% N substitution through liquid effluent	67.70	66.10	66.90	15.72	16.18	15.95	4.41	4.56	4.48	164.92	173.82	169.40
S2 – 100% N substitution through solid effluent	68.20	65.40	66.80	15.92	16.61	16.26	4.46	4.64	4.55	170.65	177.56	174.10
S3 – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	67.30	66.50	66.90	15.90	16.14	16.02	4.46	4.54	4.50	168.32	173.01	170.66
S4 – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	66.90	65.70	66.30	16.92	17.24	17.08	4.75	4.84	4.79	190.90	194.34	192.62
S5 – 50% N substitution through solid effluent + 50% N substitution through inorganic source	66.30	65.10	65.70	17.44	17.96	17.70	4.88	5.04	4.96	200.30	200.82	205.06
S6 – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	66.60	65.60	66.10	17.01	17.25	17.13	4.78	4.84	4.81	191.36	194.15	192.75
S7 – 25% N substitution through solid effluent + 75% N substitution through inorganic source	66.10	66.50	65.80	17.46	17.76	17.61	4.90	4.98	4.94	200.40	205.70	203.03
S8 – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	67.10	65.70	66.80	15.92	16.40	16.16	4.46	4.60	4.53	169.82	174.68	172.25
S9 – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	67.50	66.70	67.10	15.75	15.95	15.85	4.43	4.49	4.46	166.63	168.53	167.58
S10 – 100% N substitution through inorganic source	65.90	65.70	65.80	17.46	17.54	17.50	4.90	4.93	4.91	200.56	201.52	201.04
S.E.m±	0.49	0.53	0.36	0.20	0.28	0.17	0.05	0.06	0.04	3.40	3.72	2.52
CD at 5%	1.45	1.57	1.03	0.59	0.83	0.49	0.15	0.18	0.11	10.09	11.05	7.23

recorded with S₅ over other substitution levels except S₇ and S₁₀. Significantly the lowest weight per cob (157.58) was recorded at S₉ which was found on par with S₁, S₃, S₈, and S₂.

4.1.2.4 Number of grains per cob (Table 14)

Number of grains per cob differed significantly with nitrogen substitution level. Significantly higher number of grains per cob was recorded at S₅ (543.50) however, it was found on par with nitrogen substitution levels of S₇ and S₁₀. Whereas, significantly lower number of grains per cob was recorded at S₉ (487.18) as compared to other nitrogen substitution levels except S₁, S₃, S₈, and S₂.

4.1.2.5 Grain weight per cob (g) (Table 14)

Nitrogen substitution through distillery effluents influenced the grain weight per cob significantly. Substitution level of S₅ recorded significantly higher grain weight per cob of 173.51 at S₅ which was found significantly superior to all the substitution levels except S₇ and S₁₀. Substitution level of S₉ recorded significantly lowest grain weight per cob (141.20).

4.1.2.6 Test weight (100-grain weight) (Table 14)

Test weight was significantly influenced by application of distillery effluents as a source of nitrogen. Substitution level S₅ recorded significantly higher test weight (30.08) as compared to other nitrogen substitution levels but was found on par with S₇ and S₁₀. While, substitution level of S₉ recorded significantly lowest test weight (26.93) followed by test weights at S₁, S₃, S₈, and S₂.

Table 14. Number of grains per cob, grain weight per cob (g) and test weight (100-grain weight) of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Number of grains per cob			Grain weight per cob			100-grain weight		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	483.04	496.86	489.95	139.07	146.54	142.80	26.72	27.48	27.10
S ₂ – 100% N substitution through solid effluent	486.70	508.16	497.43	141.60	153.40	147.50	27.04	28.22	27.63
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	485.50	497.74	491.62	141.13	146.53	143.83	27.01	27.43	27.22
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	519.25	529.16	542.20	160.34	164.15	162.24	28.78	29.30	29.04
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	535.90	551.10	543.50	168.89	178.14	173.51	29.65	30.51	30.08
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	521.86	529.96	525.91	160.82	165.49	163.15	28.90	29.34	29.12
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	536.80	544.10	540.45	169.32	174.32	171.82	29.68	30.20	29.94
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	488.09	502.95	495.52	142.03	149.94	146.00	27.05	27.83	27.44
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	484.26	490.10	487.18	139.59	142.82	141.20	26.76	27.10	26.93
S ₁₀ – 100% N substitution through inorganic source	536.86	538.54	538.20	169.39	170.84	170.11	29.69	29.81	29.75
S.E.m±	6.80	6.91	4.85	3.16	3.20	2.25	0.32	0.38	0.25
CD at 5%	20.19	20.52	13.92	9.38	9.50	6.46	0.95	1.13	0.72

4.1.2.7 Grain yield (q/ha) (Table 15 and Fig.6)

Grain yield of maize differed significantly due to substitution of nitrogen with distillery effluents. Significantly higher grain yield (70.17) was recorded at S₅ over rest of nitrogen substitution levels but was found on par with S₇ and S₁₀. Further, grain yield at S₁₀ (69.40) was found on par with 25 per cent substitution through liquid effluent plus 75 per cent substitution through inorganic source (S₆) and 50 per cent substitution through liquid effluent plus 50 per cent substitution through inorganic source (S₄). While, significantly lower grain yield (62.81) was recorded at S₉ which was found on par with grain yield at S₁ (63.17), S₃ (63.51), S₈ (64.02) and S₂ (64.44).

4.1.2.8 Stover yield (q/ha) (Table 15 and Fig.6)

Nitrogen substitution through distillery effluents had significant influence on stover yield of maize. Substitution level of S₅ registered significantly higher stover yield (98.47) over other nitrogen substitution levels and was found on par with stover yields at S₇ (97.71) and S₁₀ (97.50). Stover yield at S₁₀ was further found on par with S₆ and S₄. Whereas, significantly the lowest stover yield of 89.85 was recorded at S₉ followed by S₁ (90.10), S₃ (90.55), S₈ (91.16) and S₂ (91.37) however all these nitrogen substitution levels were found on par among themselves.

4.1.2.9 Harvest index (Table 15)

Harvest index (HI) in maize, varied significantly due to variation in nitrogen substitution levels by distillery effluents. Substitution level of S₅ recorded higher harvest index (0.416) which was significantly superior to other substitution levels except S₇, S₁₀, S₆, S₄ and S₂. Whereas, significantly lowest harvest index of 0.411 was recorded with substitution level of S₉.

Table 15. Grain yield (q/ha), stover yield (q/ha) and harvest index (HI) of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Grain yield			Stover yield			Harvest index		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	62.28	64.06	63.17	89.05	91.16	90.10	0.411	0.413	0.412
S ₂ – 100% N substitution through solid effluent	63.05	65.83	64.44	90.51	92.23	91.37	0.411	0.416	0.413
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	62.98	64.04	63.51	89.90	91.21	90.55	0.412	0.412	0.412
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	67.16	68.44	67.80	94.90	96.54	95.70	0.415	0.415	0.414
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	69.19	71.18	70.17	97.09	99.85	98.47	0.416	0.416	0.416
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	67.43	68.47	67.95	95.18	96.66	95.92	0.416	0.416	0.415
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	69.20	70.41	69.80	96.95	98.47	97.71	0.417	0.417	0.416
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	63.06	64.98	64.02	89.20	92.52	91.16	0.413	0.413	0.412
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	62.43	63.19	62.81	89.31	90.39	89.85	0.412	0.412	0.411
S ₁₀ – 100% N substitution through inorganic source	69.23	69.57	69.40	97.30	97.75	97.50	0.417	0.417	0.416
S.E.m±	0.80	0.84	0.58	1.01	1.06	0.73	0.002	0.002	0.001
CD at 5%	2.38	2.49	1.66	2.99	3.15	2.10	0.006	0.006	0.003

LEGEND

Nitrogen Substitution levels

- S₁ - 100 per cent nitrogen substitution through liquid effluent
- S₂ - 100 per cent nitrogen substitution through solid effluent
- S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent
- S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic
- S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic
- S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic
- S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic
- S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent
- S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent
- S₁₀ - 100% nitrogen through inorganic (100:75:50 kg N:P₂O₅:K₂O/ha).

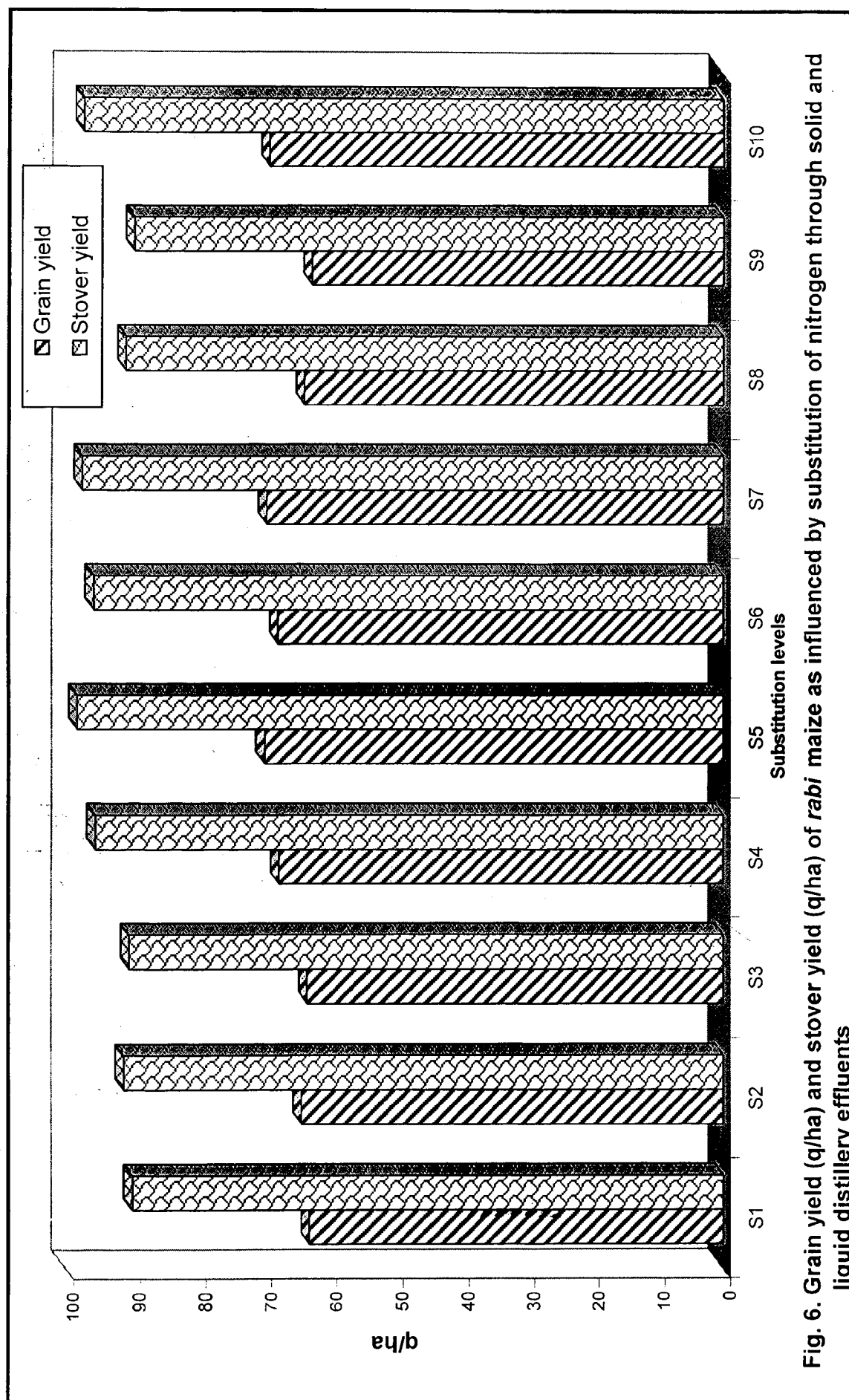


Fig. 6. Grain yield (q/ha) and stover yield (q/ha) of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

4.1.3 Quality parameters

4.1.3.1 Protein (%) (Table 16)

Protein content in grain differed significantly due to substitution of nitrogen by distillery effluents. Significantly higher protein contents were recorded at S₅ (11.14), S₇ (11.09) and S₁₀ (11.04) which were found significantly superior to rest of substitution levels and all these three substitution levels were found on par among themselves. Significantly lowest protein content (10.04) was recorded at substitution level of S₉.

4.1.3.2 Reducing sugar (%) (Table 16)

Reducing sugar content in grains was not influenced significantly by substitution of nitrogen with distillery effluents.

4.1.3.3 Starch (%) (Table 16)

The different substitution levels of nitrogen with distillery effluents did not bring significant influence on starch content in grain.

4.1.4 Nutrient contents in plant

4.1.4.1 Nutrient contents in plant at anthesis

4.1.4.1.1 Nitrogen (%) (Table 17)

Nitrogen content in plant differed significantly due to nitrogen substitution levels. Significantly higher nitrogen content (3.17) was recorded at S₅ followed by S₇ and S₁₀. Whereas, significantly lowest nitrogen content in plant at anthesis was recorded at S₉ (2.84).

4.1.4.1.2 Phosphorus (%) (Table 17)

The nitrogen substitution levels did not vary significantly for phosphorus content in plant at anthesis.

Table 16. Protein, reducing sugar and starch contents (%) in *rabi* maize grain as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Protein			Reducing sugar			Starch		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	10.01	10.05	10.05	1.23	1.25	1.24	65.68	67.40	66.50
S ₂ – 100% N substitution through solid effluent	10.12	10.34	10.23	1.24	1.26	1.25	67.26	67.29	67.27
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	10.05	10.11	10.08	1.22	1.27	1.24	65.63	67.29	66.46
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	10.83	10.91	10.87	1.20	1.24	1.22	67.20	67.22	67.21
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	11.02	11.26	11.14	1.23	1.24	1.23	67.10	67.16	67.13
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	10.84	10.98	10.91	1.20	1.23	1.21	67.18	67.20	67.19
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	11.03	11.15	11.09	1.21	1.24	1.22	67.16	67.17	67.16
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	10.13	10.19	10.16	1.24	1.25	1.24	67.20	67.30	67.25
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	10.02	10.06	10.04	1.22	1.25	1.23	67.32	67.31	67.31
S ₁₀ – 100% N substitution through inorganic source	11.03	11.05	11.04	1.21	1.23	1.22	67.22	67.25	67.23
S.E.m±	0.07	0.07	0.05	0.03	0.03	0.02	0.61	0.71	0.47
CD at 5%	0.21	0.21	0.14	NS	NS	NS	NS	NS	NS

NS – Non significant.

4.1.4.1.3 Potassium (%) (Table 17)

Potassium content in plant varied significantly due to nitrogen substitution levels through distillery effluents. Significantly higher potassium content in plant was recorded at S₁ (1.91) as compared to other nitrogen substitution levels but was found on par with S₉, S₃, S₈ and S₂.

4.1.4.2 Nutrient contents in grain and stover and total uptake at harvest

4.1.4.2.1 Nitrogen contents (%) in grain and stover and total nitrogen uptake (kg/ha) (Table 18 and Fig.7)

Substitution of nitrogen using distillery effluents had significant influence on nitrogen content in grain and stover. Significantly higher nitrogen contents in grain (1.78) and stover (0.457) were recorded at S₅ which was found on par with S₇ and S₁₀. While, substitution level of S₉ recorded significantly lowest nitrogen content in grain (1.60) and stover (0.414) followed by S₁.

ii Nitrogen substitution levels had significant influence on total uptake of nitrogen by maize crop. Significantly higher total uptake of 169.93 was recorded at S₅ over other nitrogen substitution levels but was found on par with S₇ and S₁₀. Significantly the lowest total uptake was recorded with S₉ (138.01).

4.1.4.2.2 Phosphorus contents (%) in grain and stover and total phosphorus uptake (kg/ha) (Table 19 and Fig.7)

Substitution of nitrogen using distillery effluents did not influence significantly on phosphorus contents in grain and stover. However, substitution levels brought significant variation on total phosphorus uptake. Substitution level S₅ recorded significantly higher total phosphorus uptake of 37.62 over other substitution levels but was found

Table 17. Nitrogen, phosphorus and potassium contents (%) of *rabi* maize at anthesis as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Nitrogen			Phosphorus			Potassium		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	2.81	2.87	2.84	0.327	0.331	0.329	1.90	1.92	1.91
S ₂ – 100% N substitution through solid effluent	2.84	2.94	2.89	0.329	0.332	0.330	1.88	1.71	1.89
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	2.83	2.91	2.87	0.327	0.329	0.328	1.89	1.91	1.90
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	3.05	3.09	3.07	0.322	0.325	0.324	1.86	1.88	1.87
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	3.12	3.22	3.17	0.324	0.326	0.325	1.85	1.88	1.86
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	3.05	3.09	3.07	0.321	0.325	0.323	1.86	1.87	1.86
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	3.12	3.20	3.16	0.323	0.325	0.324	1.85	1.86	1.85
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	2.86	2.94	2.90	0.327	0.331	0.329	1.88	1.90	1.89
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	2.82	2.86	2.84	0.327	0.329	0.328	1.89	1.91	1.90
S ₁₀ – 100% N substitution through inorganic source	3.13	3.15	3.14	0.321	0.323	0.322	1.84	1.85	1.84
S.E.m±	0.04	0.04	0.03	0.004	0.005	0.003	0.01	0.02	0.01
CD at 5%	0.12	0.15	0.09	NS	NS	NS	0.03	0.06	0.03

NS – Non significant

Table 18. Nitrogen contents (%) in grain and stover and total nitrogen uptake (kg/ha) by *rabi* maize at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Nitrogen content								Total uptake		
	Grain				Stover						
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001
S ₁ – 100% N substitution through liquid effluent	1.60	1.61	1.60	0.410	0.421	0.415	136.16	141.52	138.84		
S ₂ – 100% N substitution through solid effluent	1.62	1.65	1.63	0.414	0.428	0.421	139.61	148.09	143.85		
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	1.61	1.62	1.61	0.413	0.419	0.416	138.53	143.88	141.20		
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	1.73	1.75	1.74	0.437	0.447	0.442	157.66	162.92	160.29		
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	1.76	1.80	1.78	0.450	0.464	0.457	165.46	174.40	169.93		
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	1.73	1.76	1.74	0.439	0.448	0.443	158.43	163.81	161.12		
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	1.76	1.78	1.77	0.452	0.460	0.456	165.61	170.62	168.11		
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	1.62	1.63	1.62	0.415	0.421	0.418	139.43	144.87	142.15		
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	1.60	1.61	1.60	0.411	0.417	0.414	136.60	139.42	138.01		
S ₁₀ – 100% N substitution through inorganic source	1.76	1.77	1.76	0.452	0.454	0.453	165.82	167.52	166.67		
S.E.m±	0.01	0.02	0.01	0.004	0.004	0.003	3.12	3.34	2.28		
CD at 5%	0.03	0.06	0.03	0.012	0.012	0.008	9.27	9.92	6.54		

Table 19. Phosphorus contents (%) in grain and stover and total phosphorus uptake (kg/ha) by *rabi* maize at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Phosphorus content						Total uptake		
	Grain			Stover			1999-2000	2000-2001	Pooled
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled			
S ₁ – 100% N substitution through liquid effluent	0.278	0.282	0.280	0.188	0.191	0.189	34.05	35.47	34.76
S ₂ – 100% N substitution through solid effluent	0.280	0.285	0.282	0.189	0.193	0.191	34.76	36.56	35.66
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	0.276	0.280	0.278	0.188	0.190	0.189	34.28	35.26	34.77
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	0.274	0.275	0.274	0.189	0.190	0.189	36.34	37.16	36.75
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	0.272	0.274	0.273	0.186	0.189	0.187	36.88	38.36	37.62
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	0.273	0.276	0.274	0.185	0.187	0.186	36.02	36.97	36.49
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	0.272	0.273	0.272	0.185	0.188	0.186	36.75	37.73	37.24
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	0.278	0.280	0.279	0.188	0.192	0.190	34.41	35.95	35.18
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	0.279	0.282	0.281	0.189	0.193	0.191	34.30	35.26	34.78
S ₁₀ – 100% N substitution through inorganic source	0.270	0.272	0.271	0.184	0.185	0.185	36.59	37.00	36.79
S.E.m±	0.005	0.006	0.004	0.003	0.004	0.002	0.49	0.61	0.39
CD at 5%	NS	NS	NS	NS	NS	NS	1.45	1.81	1.12

NS – Non significant

on par with S₇, S₁₀ and S₄. Whereas, significantly lowest total uptake (34.78) was recorded at S₁.

4.1.4.2.3 Potassium contents (%) in grain and stover and total potassium uptake (kg/ha) (Table 20 and Fig.7)

Application of distillery effluents influenced potassium contents in grain but not in stover. Significantly higher potassium content (0.369) in grain was recorded with S₁ followed by S₂. Whereas, significantly lowest potassium content (0.342) was recorded at S₁₀.

The total uptake was influenced significantly by substitution levels. Significantly higher total potassium uptake was recorded at S₅ (147.52) as compared to other nitrogen substitution levels however it was found on par with S₇, S₁₀, S₆ and S₄. Whereas, significantly lower total potassium uptake of 136.41 was recorded with S₉ over other substitution levels except S₁, S₃, S₈ and S₂.

4.1.4.2.4 Zinc contents (ppm) in grain and stover and total zinc uptake (kg/ha) (Table 21)

Neither in grain nor in stover, nitrogen substitution levels brought significant influence on zinc content. However, total zinc uptake was influenced significantly by nitrogen substitution levels and significantly higher total zinc uptake (0.423) was recorded at S₅ as compared to all the nitrogen substitution levels except S₇. Substitution level of S₁ recorded significantly the lowest total zinc uptake of zinc (0.321).

4.1.4.2.5 Copper contents (ppm) in grain and stover and total copper uptake (kg/ha) (Table 21)

Copper contents in grain and stover was not influenced significantly by application distillery effluents as a source of nitrogen. But nitrogen substitution levels brought significant influence on total copper

Table 20. Potassium contents (%) in grain and stover and total potassium uptake (kg/plant) by *rabi* maize at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Potassium content						Total uptake		
	Grain			Stover					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	0.358	0.362	0.369	1.27	1.29	1.28	135.39	140.79	138.09
S ₂ – 100% N substitution through solid effluent	0.358	0.360	0.359	1.28	1.29	1.28	138.42	142.68	140.55
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	0.357	0.359	0.358	1.26	1.27	1.27	135.75	138.83	137.29
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	0.345	0.349	0.347	1.23	1.25	1.24	139.90	144.56	142.23
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	0.346	0.350	0.348	1.24	1.26	1.25	144.33	150.71	147.52
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	0.342	0.344	0.343	1.24	1.25	1.24	141.08	144.37	142.73
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	0.344	0.347	0.346	1.22	1.24	1.23	142.08	146.53	144.30
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	0.353	0.363	0.358	1.25	1.28	1.27	134.51	142.01	138.26
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	0.353	0.357	0.355	1.26	1.28	1.27	134.57	138.26	136.41
S ₁₀ – 100% N substitution through inorganic source	0.341	0.343	0.342	1.22	1.23	1.22	142.32	144.09	143.20
S.E.m±	0.004	0.005	0.003	0.02	0.03	0.02	2.65	3.06	2.02
CD at 5%	0.012	0.015	0.009	NS	NS	NS	7.87	9.09	5.79

NS – Non significant

LEGEND

Nitrogen Substitution levels

- S₁ - 100 per cent nitrogen substitution through liquid effluent
- S₂ - 100 per cent nitrogen substitution through solid effluent
- S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent
- S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic
- S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic
- S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic
- S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic
- S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent
- S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent
- S₁₀ - 100% nitrogen through inorganic (100:75:50 kg N:P₂O₅:K₂O/ha).

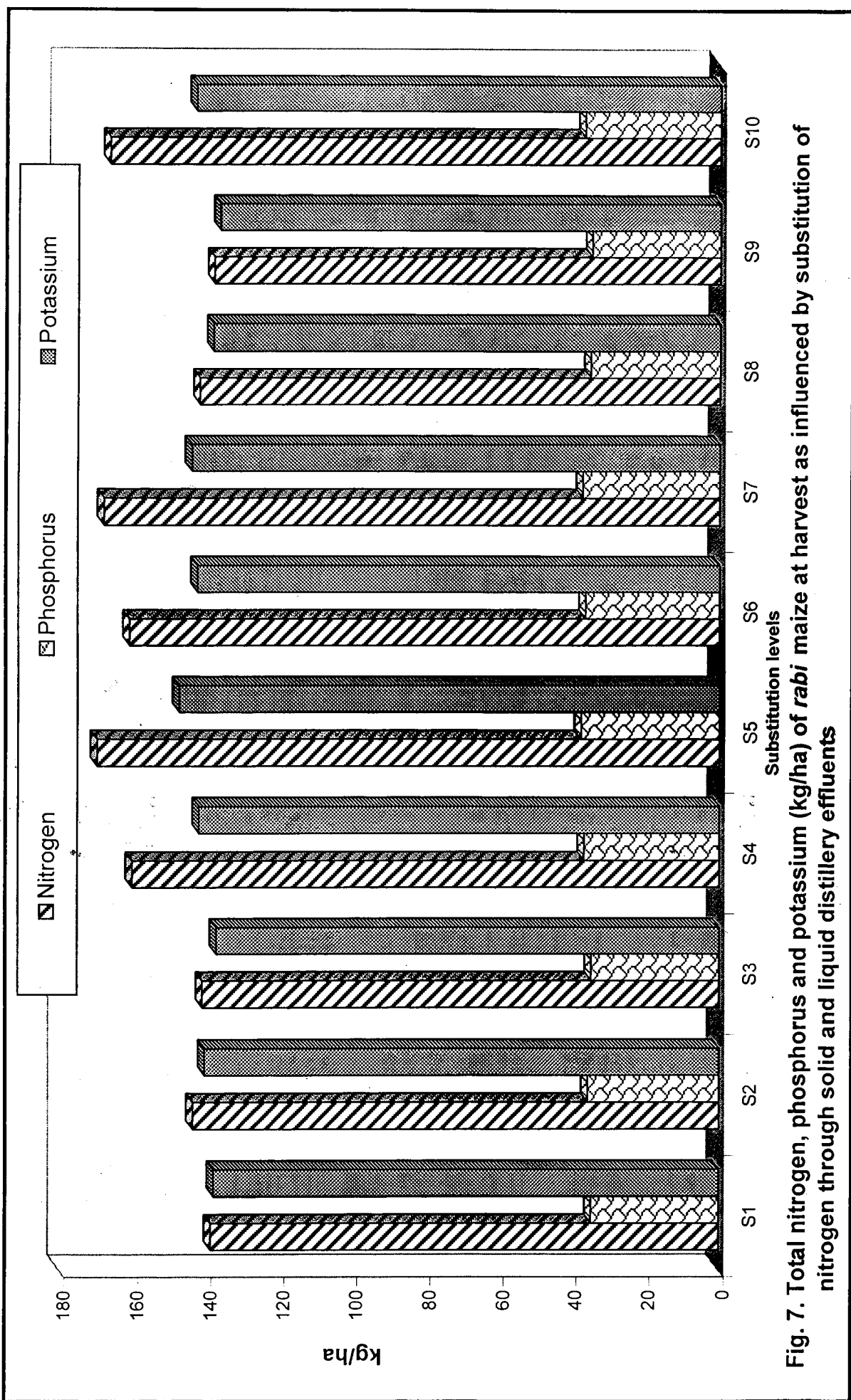


Fig. 7. Total nitrogen, phosphorus and potassium (kg/ha) of *rabi* maize at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Table 21. Zinc and copper contents (ppm) in grain and stover and total zinc and copper uptake (kg/ha) by *rabi* maize at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Zinc						Copper					
	Grain			Stover			Grain			Stover		
	Zinc content			Zinc content			Copper content			Copper content		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	21.10	21.30	21.20	28.50	28.55	28.52	7.77	7.80	7.78	10.43	10.45	10.44
S ₂ – 100% N substitution through solid effluent	21.20	21.25	21.22	28.61	28.63	28.62	7.80	7.81	7.80	10.45	10.46	10.45
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	21.08	21.12	21.10	28.49	28.55	28.52	7.73	7.75	7.74	10.43	10.46	10.44
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	20.40	20.51	20.45	28.12	28.13	28.12	7.70	7.72	7.71	10.36	10.38	10.37
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	20.78	20.80	20.79	28.10	28.16	28.13	7.72	7.73	7.72	10.38	10.40	10.39
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	20.35	20.38	20.36	27.75	27.80	27.77	7.69	7.70	7.69	10.35	10.37	10.36
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	20.70	20.78	20.74	28.10	28.15	28.10	7.69	7.72	7.70	10.37	10.39	10.38
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	21.94	22.02	21.18	28.30	28.35	28.32	7.69	7.70	7.69	10.41	10.44	10.42
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	21.90	21.98	21.94	28.15	28.30	28.22	7.72	7.74	7.73	10.41	10.43	10.41
S ₁₀ – 100% N substitution through inorganic source	20.33	20.35	20.34	27.60	27.80	27.10	7.68	7.70	7.69	10.35	10.37	10.36
S.E.m±	0.52	0.91	0.50	0.57	0.55	0.40	0.13	0.12	0.09	0.15	0.17	0.11
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
							0.004	0.006	0.004	0.005	0.005	0.003
							0.011	0.018	0.015	0.012	0.015	0.009

NS – Non significant

uptake. Significantly higher total copper uptake (0.156) was recorded with S₅ over other substitution levels but was found on par with S₇, S₁₀, S₆ and S₄. Whereas, significantly lowest total copper uptake of 0.143 was recorded with S₉ and S₁.

4.1.4.2.6 Iron contents (ppm) in grain and stover and total iron uptake (kg/ha) (Table 22)

Substitution of nitrogen by distillery effluents had no significant influence on iron contents in grain and stover. Whereas, total iron uptake was influenced significantly by nitrogen substitution levels. Significantly higher total iron uptake was recorded at S₅ (2.84) as compared to other nitrogen substitution levels except S₇ and S₁₀. While, significantly the lowest total iron uptake of 2.58 was recorded at S₉.

4.1.4.2.7 Manganese contents (ppm) in grain and stover and total manganese uptake (kg/ha) (Table 22)

Manganese contents in grain and stover were not influenced significantly by nitrogen substitution levels. However, total manganese uptake influenced significantly by nitrogen substitution level. Substitution level of S₅ recorded significantly highest total manganese uptake (1.27) which was found on par with S₇, S₁₀, S₆, S₄ and S₂. Significantly the lowest total manganese uptake (1.16) was recorded at S₉ and S₁.

4.1.5 Physico-chemical properties of soil

4.1.5.1 Physical properties

4.1.5.1.1 Bulk density (Mg/m³) (Table 23)

The nitrogen substitution levels did not influence significantly on bulk density of soil.

Table 22. Iron and manganese contents (ppm) in grain and stover and total iron and manganese uptake (kg/ ha) by *rabi* maize at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Iron						Manganese					
	Grain			Stover			Grain			Stover		
	Iron content			Iron content			Manganese content			Manganese content		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	157.40	157.74	157.57	177.26	177.55	177.40	21.15	21.25	21.20	114.80	114.95	114.87
S ₂ – 100% N substitution through solid effluent	157.45	157.71	157.58	177.38	177.70	177.54	21.20	21.25	21.22	115.40	115.50	115.45
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	157.30	157.35	157.32	177.60	177.65	177.62	21.18	21.22	21.20	114.50	114.55	114.52
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	157.20	157.23	157.21	176.30	176.40	176.35	21.09	21.16	21.12	113.70	113.75	113.72
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	157.24	157.28	157.26	176.50	176.55	176.52	21.10	21.15	21.12	113.75	113.85	113.80
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	157.00	157.30	157.15	175.80	175.85	175.82	20.78	20.90	20.84	113.00	113.25	113.12
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	157.18	157.20	157.19	176.00	176.10	176.05	21.05	21.10	21.07	113.30	113.40	113.35
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	157.25	157.30	157.27	177.38	177.54	177.46	21.15	21.22	21.18	114.03	114.73	114.38
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	157.20	157.25	157.22	177.25	177.59	177.42	21.10	21.20	21.15	114.20	114.30	114.25
S ₁₀ – 100% N substitution through inorganic source	156.80	157.90	156.90	175.60	175.87	175.73	20.75	20.82	20.77	112.80	112.90	112.85
S.E.m±	0.99	0.98	0.70	3.41	3.37	2.40	0.50	0.48	0.35	1.50	1.53	1.07
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Total uptake							20.75	20.82	20.77	112.80	112.90	112.85
							0.03	0.03	0.03	0.03	0.03	0.03
							0.09	0.09	0.09	0.09	0.09	0.09

NS – Non significant

4.1.5.2 Chemical properties

4.1.5.2.1 Soil reaction (pH) (Table 23)

The substitution of nitrogen by distillery effluents did not influence significantly on soil reaction.

4.1.5.2.2 Electrical conductivity (dSm^{-1}) (Table 23)

Electrical conductivity of soil was influenced significantly by nitrogen substitution levels and significantly higher electrical conductivity of 0.63 was recorded at S_1 which found on par with S_9 and S_8 . While, substitution level of S_{10} recorded significantly the lowest electrical conductivity (0.46).

4.1.5.2.3 Organic carbon (%) (Table 23)

Organic carbon content of soil was not influenced significantly by substitution of nitrogen by distillery effluents.

4.1.5.2.4 Nutrient content in soil

4.1.5.2.4.1 Available nitrogen (kg/ha) (Table 24 and Fig.8)

The substitution levels of nitrogen by distillery effluents brought significant influence on available nitrogen content in soil. Significantly higher available nitrogen (251.77) was recorded at S_9 as compared to other nitrogen substitution levels but was found on par with S_1 , S_3 , S_8 and S_2 . Whereas, significantly the lowest available nitrogen content (226.12) was recorded at S_5 .

4.1.5.2.4.2 Available phosphorus (kg/ha) (Table 24 and Fig.8)

Available phosphorus content in soil influenced significantly due to nitrogen substitution levels. Substitution level of S_2 recorded significantly

Table 23. Bulk density (Mg/m^3), soil reaction (pH), electrical conductivity (EC, dSm^{-1}) and organic carbon (OC, %) in soil after harvest of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Bulk density			pH			EC			OC		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	1.50	1.49	1.49	7.15	7.18	7.17	0.62	0.65	0.63	0.49	0.50	0.49
S ₂ – 100% N substitution through solid effluent	1.49	1.48	1.48	7.10	7.12	7.11	0.58	0.60	0.59	0.50	0.51	0.50
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	1.51	1.50	1.50	7.13	7.14	7.14	0.55	0.58	0.57	0.49	0.50	0.49
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	1.52	1.51	1.51	7.16	7.14	7.14	0.53	0.55	0.54	0.50	0.53	0.51
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	1.50	1.48	1.49	7.10	7.11	7.10	0.53	0.55	0.54	0.49	0.53	0.51
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	1.52	1.51	1.51	7.12	7.11	7.11	0.55	0.56	0.55	0.50	0.51	0.50
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	1.51	1.49	1.50	7.14	7.15	7.14	0.54	0.55	0.54	0.48	0.52	0.49
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	1.49	1.48	1.48	7.13	7.14	7.13	0.58	0.60	0.59	0.49	0.51	0.50
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	1.50	1.48	1.49	7.15	7.17	7.16	0.60	0.64	0.62	0.48	0.49	0.48
S ₁₀ – 100% N substitution through inorganic source	1.52	1.51	1.51	7.11	7.10	7.10	0.44	0.48	0.46	0.48	0.46	0.47
S.Em±	0.07	0.05	0.04	0.13	0.11	0.08	0.03	0.02	0.02	0.04	0.04	0.03
CD at 5%	NS	NS	NS	NS	NS	NS	0.09	0.06	0.05	NS	NS	NS

NS – Non significant

LEGEND

Nitrogen Substitution levels

- S₁ - 100 per cent nitrogen substitution through liquid effluent
- S₂ - 100 per cent nitrogen substitution through solid effluent
- S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent
- S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic
- S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic
- S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic
- S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic
- S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent
- S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent
- S₁₀ - 100% nitrogen through inorganic (100:75:50 kg N:P₂O₅:K₂O/ha).

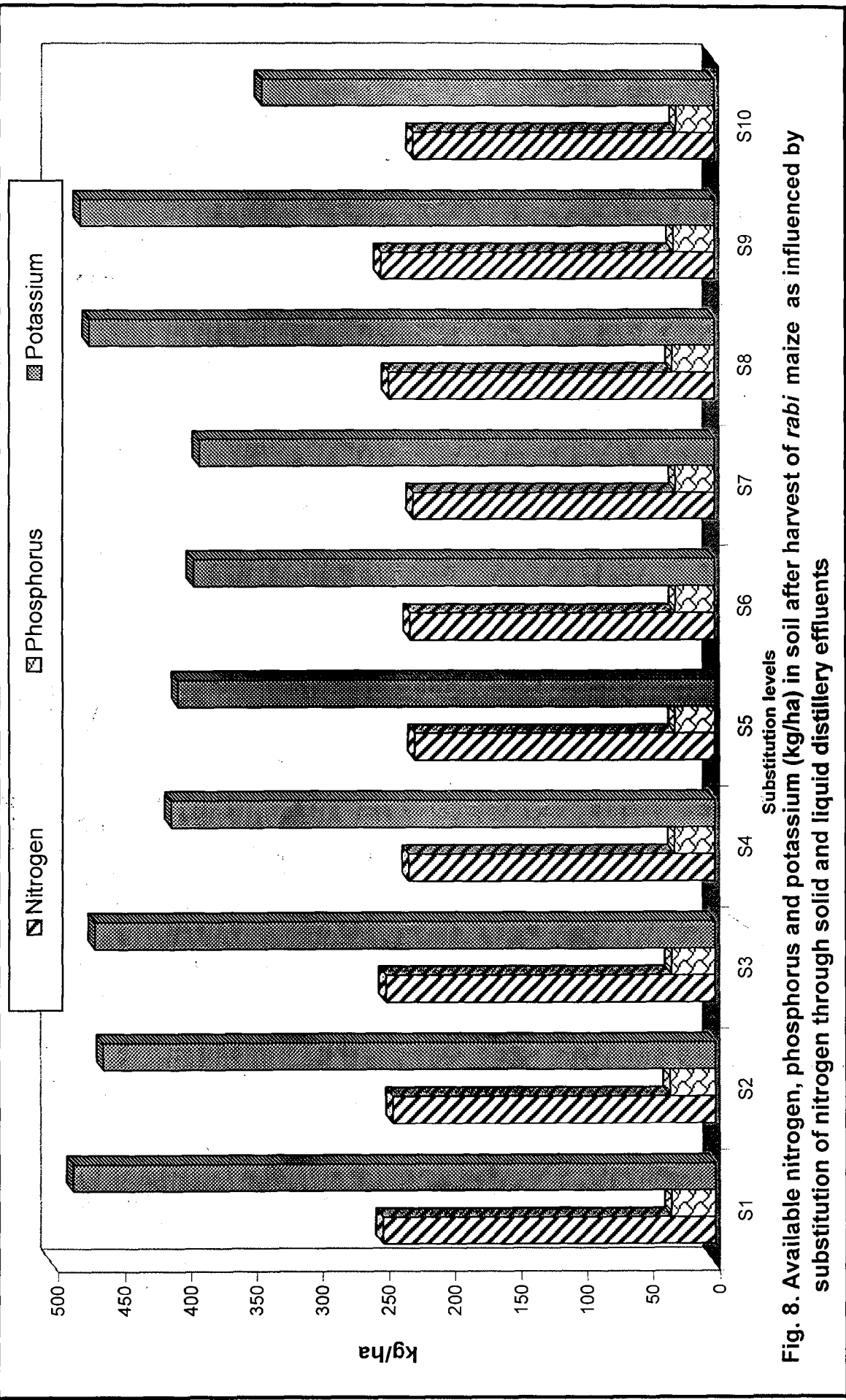


Fig. 8. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

higher available phosphorus content (33.30) over rest of the substitution levels of nitrogen but was found on par with S₉, S₁, S₃ and S₈. Whereas, significantly the lowest available phosphorus content (29.51) was recorded at S₁₀.

4.1.5.2.4.3 Available potassium (kg/ha) (Table 24 and Fig.8)

Available potassium was influenced significantly by application of distillery effluents as a source of nitrogen. Significantly the highest available potassium in soil was recorded at S₁ (484.72) which was found on par with S₉, S₈ and S₃. Significantly the lowest available potassium content (342.02) was recorded at substitution level of S₁₀.

4.1.5.2.4.4 DTPA extractable (available) micronutrients in soil (ppm) (Table 25)

4.1.5.2.4.4.1 Zinc

The substitution of nitrogen by distillery effluents did not influence significantly on available zinc in soil.

4.1.5.2.4.4.2 Copper

Copper content in soil was not influenced significantly by application of distillery effluents as a source of nitrogen.

4.1.5.2.4.4.3 Iron

Nitrogen substitution using distillery effluents had no significant influence on iron content of soil.

4.1.5.2.4.4.4 Manganese

Manganese content in soil was not influenced significantly by substitution of nitrogen with distillery effluents.

4.1.6 Economics (Rs./ha) (Table 26)

Highest gross return was obtained with 50 per cent nitrogen substitution through solid effluent plus 50 per cent nitrogen substitution through inorganic source (33,792). This was closely followed by S₇

Table 24. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Available N			Available P ₂ O ₅			Available K ₂ O		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	247.73	253.33	250.53	31.67	32.95	32.31	482.10	487.33	484.72
S ₂ – 100% N substitution through solid effluent	240.30	246.44	243.37	32.70	33.90	33.30	459.23	465.10	462.16
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	246.48	249.88	248.18	31.80	32.96	32.38	466.10	470.54	468.32
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	228.65	232.79	230.72	29.80	30.30	30.05	409.50	412.56	411.03
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	222.52	229.72	226.12	29.63	30.57	30.10	403.12	407.18	405.46
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	228.05	231.01	229.53	29.10	29.96	29.53	392.17	395.24	393.71
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	225.64	228.82	227.23	29.05	30.35	29.70	388.25	391.00	389.63
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	243.38	248.48	245.93	31.87	32.75	32.31	469.35	475.70	472.52
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	249.24	254.30	251.77	31.10	32.00	31.55	477.50	479.10	479.30
S ₁₀ – 100% N substitution through inorganic source	227.70	226.60	227.15	30.01	29.05	29.51	343.87	340.17	342.02
S.E.m±	6.02	6.70	4.50	0.67	0.71	0.49	9.05	10.09	6.77
CD at 5%	17.30	19.89	12.91	1.99	2.11	1.40	26.88	29.97	19.43

Table 25. DTPA extractable zinc, copper, iron and manganese contents (ppm) in soil after harvest of *rabi* maize as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Zinc			Copper			Iron			Manganese		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	2.11	2.13	2.12	1.80	1.82	1.81	5.13	5.19	5.16	8.96	9.01	8.98
S ₂ – 100% N substitution through solid effluent	2.12	2.13	2.13	1.80	1.84	1.82	5.15	5.20	5.17	9.00	9.03	9.01
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	2.08	2.11	2.09	1.78	1.79	1.78	5.16	5.18	5.17	8.90	8.92	8.91
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	2.10	2.15	2.12	1.75	1.76	1.75	4.92	4.95	4.93	8.72	8.78	8.76
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	2.09	2.11	2.10	1.78	1.79	1.78	5.05	5.10	5.07	8.74	8.80	8.77
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	2.08	2.10	2.09	1.75	1.77	1.76	4.88	4.92	4.90	8.63	8.69	8.66
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	2.02	2.04	2.03	1.75	1.77	1.77	5.01	5.04	5.02	8.68	8.72	8.70
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	2.12	2.14	2.13	1.77	1.80	1.78	5.15	5.17	5.16	8.86	8.92	8.89
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	2.11	2.12	2.11	1.80	1.81	1.80	5.15	5.19	5.17	8.88	8.93	8.90
S ₁₀ – 100% N substitution through inorganic source	2.00	2.05	2.02	1.76	1.77	1.76	4.80	4.90	4.85	8.62	8.60	8.61
S.Em±	0.05	0.06	0.04	0.03	0.03	0.02	0.16	0.18	0.12	0.19	0.23	0.15
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

Table 26. Economics as influenced by nitrogen substitution through solid and liquid distillery effluents in *rabi* maize

Nitrogen substitution level	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)			Net returns (Rs./ ha)			B:C ratio		
		1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	11690	30029	30878	30454	18339	19188	18764	1.57	1.64	1.60
S ₂ – 100% N substitution through solid effluent	11756	30048	31699	31054	18350	19943	19298	1.56	1.69	1.62
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	11698	30364	30870	30617	18666	19177	18919	1.59	1.64	1.61
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	12027	32357	32970	32663	20330	20943	20636	1.69	1.74	1.71
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	12335	33320	34278	33792	20985	21943	21457	1.70	1.78	1.74
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	12345	32485	32986	32736	20140	20641	20391	1.63	1.67	1.65
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	12439	33321	33900	33608	20882	21461	21169	1.68	1.72	1.70
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	11702	30384	31323	30860	18682	19621	19158	1.60	1.68	1.64
S ₉ – 25% N substitution through solid effluent + 75% N substitution through 33343 liquid effluent	11694	30103	30469	30286	18409	18775	18592	1.57	1.60	1.58
S ₁₀ – 100% N substitution through inorganic source	12227	33343	33506	33424	21116	21279	21197	1.73	1.74	1.73
S.E.m±		822	890	605	801	853	585	0.02	0.03	0.02
CD at 5%		2441	2643	1736	2379	2533	1679	0.06	0.09	0.06

(33,608) and S₁₀ (33,424). The lowest gross return was recorded in S₉ (30,286). However, the maximum net returns and highest benefit:Cost ratio were obtained with nitrogen substitution level of S₅ (21,457 and 1.74) which found on par with S₁₀, S₇, S₄ and S₆. The lowest net returns and benefit:cost ratio were noticed in S₉ (18,592 and 1.58).

4.2 Experiment 2 : Studies on use of distillery effluent (Solid and Liquid effluents) as a source of nitrogen on the performance of wheat

4.2.1 Growth parameters

4.2.1.1 Plant height (cm) (Table 27)

The nitrogen substitution levels with distillery effluents influenced significantly on plant height at all growth stages. Significantly higher plant heights of 6.75, 57.36 and 81.61 were recorded at 30, 60 and 90 days after sowing (DAS), respectively with nitrogen substitution level of 50 per cent through solid effluent plus 50 per cent through inorganic source (S₅) over rest of nitrogen substitution levels but was found on par with nitrogen substitution levels of 25 per cent through solid effluent plus 75 per cent through inorganic source (S₇) and 100 per cent through inorganic source (S₁₀) at 60 and 90 DAS. Whereas, significantly lowest plant heights were recorded at nitrogen substitution level of 25 per cent through solid effluent plus 75 per cent through liquid effluent (S₉) at all growth stages (6.20, 52.69 and 74.80 at 30, 60 and 90 DAS) followed by nitrogen substitution level of 100 per cent through liquid effluent (S₁).

4.2.1.2 Leaf area index (Table 28)

Leaf area index (LAI) showed significant variation due to nitrogen substitution by distillery effluents. Nitrogen substitution level of S₅ recorded significantly higher LAI (1.93, 3.15 and 1.78) at all growth

Table 27. Plant height (cm) at different growth stages in wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	30 DAS				60 DAS				90 DAS			
	1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled	
S ₁ – 100% N substitution through liquid effluent	6.12	6.34	6.23		52.09	53.93	53.01		73.74	76.95	75.34	
S ₂ – 100% N substitution through solid effluent	6.15	6.57	6.36		51.89	56.23	54.06		73.88	80.04	76.96	
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	6.23	6.34	6.28		52.95	53.81	53.38		75.40	76.91	76.15	
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	6.34	6.48	6.41		53.91	55.22	54.51		76.58	78.29	77.43	
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	6.61	6.89	6.75		56.22	58.51	57.36		79.98	83.24	81.61	
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	6.55	6.74	6.64		54.14	55.78	54.96		76.60	79.74	78.17	
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	6.65	6.83	6.74		56.45	58.17	57.31		80.25	82.76	81.50	
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	6.19	6.41	6.30		51.68	55.42	53.55		73.10	79.21	76.15	
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	6.18	6.22	6.20		52.51	52.87	52.69		74.28	75.32	74.80	
S ₁₀ – 100% N substitution through inorganic source	6.69	6.72	6.71		56.87	57.18	57.02		80.85	81.17	81.01	
S.E.m±	0.12	0.26	0.14		0.40	0.50	0.32		0.41	0.44	0.30	
CD at 5%	0.36	0.77	0.40		1.19	1.48	0.92		1.22	1.31	0.86	

DAS – Days after sowing

stages of 30, 60 and 90 DAS as compared to other substitution levels. However, LAI at S₅ found on par with S₇ and S₁₀ at all growth stages, whereas, significantly the lowest LAI of 1.65, 2.66 and 1.50 with S₉ at 30, 60 and 90 DAS, respectively but was found on par with S₁, 50 per cent nitrogen substitution through liquid effluent plus 50 per cent substitution through solid effluent (S₃), 25 per cent nitrogen substitution through liquid effluent plus 75 per cent substitution through solid effluent (S₈) and 100 per cent nitrogen substitution through solid effluent (S₂).

4.2.1.3 Leaf area duration (Days) (Table 28)

Leaf area duration (LAD) of wheat differed significantly due to substitution of nitrogen by distillery effluents. Significantly higher LAD of 76.20 at 30-60 DAS and 73.95 at 60-90 DAS were recorded at S₅ followed by nitrogen substitution levels of S₇, S₁₀, S₆ and S₄. Significantly the lowest LAD of 64.65 at 30-60 DAS and 62.40 at 60-90 DAS were recorded at S₉.

4.2.1.4 Number of productive tillers per metre row length (Table 29)

The productive tillers differed significantly due to nitrogen substitution levels with distillery effluents. Significantly the highest number of productive tillers was recorded at S₅ (120.06) however was found on par with S₇ and S₁₀. While, significantly the lowest number of productive tillers was recorded at S₉ (101.65) which was found on par with S₁, S₃ and S₈.

4.2.1.5 Dry matter production and its accumulation

4.2.1.5.1 Total dry matter production (g/m row length) (Table 29)

Significant difference in total dry matter (TDM) production was found due to nitrogen substitution levels. Substitution level of S₅

Table 28. Leaf area index (LAI) and leaf area duration (LAD, days) of wheat at different growth stages as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Leaf area index (LAI)						Leaf area duration (LAD)					
	30 DAS			60 DAS			90 DAS			30-60 DAS		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	1.62	1.68	1.65	2.64	2.75	2.69	1.49	1.55	1.52	63.90	66.45	65.17
S ₂ – 100% N substitution through solid effluent	1.66	1.80	1.73	2.70	2.92	2.81	1.52	1.64	1.58	65.40	70.80	68.10
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	1.70	1.72	1.71	2.76	2.80	2.78	1.54	1.58	1.56	66.90	67.80	67.35
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	1.77	1.81	1.79	2.91	2.95	2.93	1.63	1.67	1.65	70.20	71.40	70.80
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	1.89	1.97	1.93	3.08	3.22	3.15	1.73	1.83	1.78	74.55	77.85	76.20
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	1.79	1.81	1.80	2.90	3.01	2.95	1.64	1.68	1.66	70.35	72.30	71.32
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	1.89	1.95	1.92	3.09	3.17	3.13	1.73	1.79	1.76	74.70	76.80	75.75
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	1.66	1.78	1.72	2.70	2.91	2.80	1.53	1.63	1.58	65.40	70.35	67.87
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	1.64	1.66	1.65	2.65	2.67	2.66	1.49	1.51	1.50	64.35	64.95	64.65
S ₁₀ – 100% N substitution through inorganic source	1.90	1.92	1.91	3.10	3.12	3.11	1.74	1.76	1.75	75.00	75.60	75.30
S.E.m±	0.03	0.04	0.02	0.05	0.06	0.04	0.04	0.04	0.03	2.90	3.09	2.96
CD at 5%	0.09	0.12	0.07	0.15	0.18	0.11	0.12	0.12	0.08	8.61	9.18	8.79

DAS – Days after sowing

Table 29. Number of productive tillers per metre row length and total dry matter production (g/m row length) of wheat at different growth stages as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Number of productive tillers				Total dry matter production											
					30 DAS				60 DAS				90 DAS			
	1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled	
S ₁ – 100% N substitution through liquid effluent	101.16	104.74	102.95		45.65	47.33	46.49		103.45	107.40	105.42		180.11	186.99	183.55	
S ₂ – 100% N substitution through solid effluent	103.30	111.86	107.58		46.64	50.61	48.62		104.37	115.95	110.16		184.54	199.95	192.24	
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	105.18	106.89	106.03		47.50	48.22	47.86		107.68	109.37	108.52		187.45	190.32	188.88	
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	110.62	113.08	111.85		50.02	51.12	50.57		113.40	115.89	114.64		197.69	202.50	200.09	
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	117.80	122.32	120.06		53.02	55.35	54.18		120.26	125.70	122.98		209.73	219.13	214.43	
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	111.24	114.62	112.93		50.22	51.72	50.97		113.83	117.30	115.56		198.28	204.34	201.31	
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	117.98	121.14	119.56		53.15	54.68	53.91		120.52	123.94	122.23		210.05	216.83	213.44	
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	103.23	110.74	106.98		46.67	50.03	48.35		105.85	113.41	109.63		184.36	197.62	190.99	
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	101.30	102.00	101.65		45.73	45.98	45.85		103.58	104.26	103.92		180.21	181.39	180.80	
S ₁₀ – 100% N substitution through inorganic source	118.60	119.14	118.87		53.56	53.81	53.68		121.47	121.98	121.72		211.32	212.42	211.87	
S.E.m±	2.74	3.83	2.32		0.58	0.61	0.42		1.10	1.23	0.82		1.57	1.61	1.12	
CD at 5%	8.14	11.37	6.67		1.72	1.81	1.21		3.27	3.65	2.35		4.66	4.78	3.23	

DAS – Days after sowing

recorded the highest TDM production at all growth stages (54.18, 122.98 and 214.43 at 30, 60 and 90 DAS) which found significantly superior over rest of nitrogen substitution levels except S₇ and S₁₀. Significantly the lowest TDM production of 45.85, 103.92 and 180.80 at 30, 60 and 90 DAS, respectively was recorded at S₉ and was found on par with S₁.

4.2.1.5.2 Dry matter accumulation in leaves (g/m row length) (Table 30)

Dry matter accumulation (DMA) in leaves differed significantly at all growth stages. Substitution level of S₅ recorded significantly higher DMA in leaves (29.80, 49.46 and 42.95 at 30, 60 and 90 DAS) as compared to other substitution levels of nitrogen with distillery effluents but was found on par with S₇ and S₁₀. Whereas, significantly the lowest DMA in leaves was recorded with S₉ (25.25, 41.88 and 36.25 at 30, 60 and 90 DAS, respectively) which was found on par with S₁.

4.2.1.5.3 Dry matter accumulation stem (g/m row length) (Table 31)

Significant difference in DMA in stem was noticed due to nitrogen substitution levels. Substitution level of S₅ recorded significantly higher DMA in stem at all growth stages (24.38, 51.12 and 75.62 at 30, 60 and 90 DAS, respectively) over remaining substitution levels but was found on par with S₇ and S₁₀. Significantly the lower DMA in stem was recorded at S₉ over rest of nitrogen substitution levels (20.60, 43.14 and 63.70 at 30, 60 and 90 DAS) except S₁.

4.2.1.5.4 Dry matter accumulation in ear (g/m row length) (Table 31)

Both at 60 and 90 DAS, significantly higher DMA in ear was recorded S₅ (22.40 and 95.85, respectively) was observed at S₅ over rest of nitrogen substitution levels. However, DMA in ear at S₅ found on par

Table 30. Dry matter accumulation in leaf (g/m row length) at different growth stages in wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Dry matter accumulation in leaf									
	30 DAS			60 DAS			90 DAS			Pooled
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	
S ₁ – 100% N substitution through liquid effluent	25.15	26.01	25.58	41.64	43.18	42.41	36.02	37.43	36.72	
S ₂ – 100% N substitution through solid effluent	25.66	27.87	26.73	41.21	47.43	44.32	36.86	39.94	38.40	
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	26.15	26.56	26.35	43.37	44.08	43.72	37.50	38.11	37.80	
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	27.51	28.13	27.82	45.60	46.64	46.12	39.51	40.39	39.95	
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	29.20	30.41	29.80	48.42	50.50	49.46	42.06	43.84	42.95	
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	27.64	23.46	28.05	45.80	47.21	46.50	39.70	40.93	40.31	
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	29.25	30.06	29.65	48.45	49.89	49.17	42.12	43.40	42.76	
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	25.68	27.52	26.60	42.57	45.63	44.10	36.86	39.54	38.20	
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	25.20	25.31	25.25	41.75	42.01	41.88	36.13	36.37	36.25	
S ₁₀ – 100% N substitution through inorganic source	29.48	29.59	29.53	48.90	49.04	48.97	42.30	42.46	42.38	
S.E.m±	0.40	0.41	0.30	0.49	0.51	0.36	0.57	0.56	0.40	
CD at 5%	1.19	1.25	0.86	1.45	1.51	1.03	1.69	1.66	1.15	

DAS – Days after sowing

Table 31. Dry matter accumulation in stem and ear (g/m row length) at different growth stages in wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Dry matter accumulation in stem										Dry matter accumulation in ear					
	30 DAS			60 DAS			90 DAS			Pooled	60 DAS			90 DAS		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ - 100% N substitution through liquid effluent	20.50	21.32	20.91	42.94	44.66	43.80	63.45	65.99	64.72		18.87	19.56	19.21	80.64	83.57	82.10
S ₂ - 100% N substitution through solid effluent	20.98	22.74	21.86	43.93	47.61	45.77	64.98	70.46	67.72		19.23	20.391	20.07	82.70	89.55	86.13
S ₃ - 50% N substitution through liquid effluent + 50% N substitution through solid effluent	21.35	21.66	21.50	44.71	45.33	45.05	66.10	67.02	66.56		19.60	19.96	19.78	83.85	85.19	84.52
S ₄ - 50% N substitution through liquid effluent + 50% N substitution through inorganic source	22.51	22.99	22.75	47.16	48.15	47.65	69.68	71.12	70.40		20.64	21.10	20.87	88.50	90.54	89.52
S ₅ - 50% N substitution through solid effluent + 50% N substitution through inorganic source	23.82	24.94	24.38	49.90	52.34	51.12	73.80	77.45	75.62		21.94	22.86	22.40	93.87	97.84	95.85
S ₆ - 25% N substitution through liquid effluent + 75% N substitution through inorganic source	22.58	23.26	22.92	47.30	48.72	48.01	69.91	72.05	70.98		20.73	21.37	21.05	88.67	91.37	90.02
S ₇ - 25% N substitution through solid effluent + 75% N substitution through inorganic source	23.90	24.62	24.26	50.06	51.56	50.81	74.01	76.19	75.10		22.01	22.49	22.25	93.92	97.24	95.18
S ₈ - 25% N substitution through liquid effluent + 50% N substitution through solid effluent	20.99	22.51	21.75	43.97	47.13	45.55	64.99	69.65	67.32		19.31	20.65	19.98	82.51	88.43	85.47
S ₉ - 25% N substitution through solid effluent + 75% N substitution through liquid effluent	20.53	20.67	20.60	42.99	43.29	43.14	63.51	63.89	63.70		18.84	18.96	18.90	80.57	81.13	80.85
S ₁₀ - 100% N substitution through inorganic source	24.08	24.22	24.15	50.42	50.72	50.57	74.42	74.78	74.75		22.15	22.22	22.18	94.60	95.18	94.89
S.E.m±	0.40	0.44	0.30	0.79	0.85	0.57	0.87	1.02	0.67		0.46	0.50	0.34	0.74	0.79	0.54
CD at 5%	1.19	1.31	0.85	2.35	2.52	1.66	2.58	3.03	1.92		1.36	1.48	0.97	2.20	2.35	1.55

DAS - Days after sowing

with S₇ and S₁₀. While, significantly the lowest DMA in ear was recorded at S₉ at both stages of 60 and 90 DAS (18.90 and 80.85, respectively).

4.2.1.6 Days to 50 per cent heading (Table 32)

Days to 50 per cent heading was influenced significantly nitrogen substitution levels by distillery effluents substitution levels of S₅, took significantly more number of days to 50 per cent heading (56.40) however was found on par with S₇, S₁₀, S₆ and S₄. Whereas substitution level of S₉ took significantly lowest number of days to 50 per cent heading (52.90) but was found on par with S₁, S₃ and S₈.

4.2.2 Yield and yield parameters

4.2.2.1 Ear length (cm) (Table 32)

The different nitrogen substitution levels brought significant influence on ear length. Significantly longest ear length (10.32) was recorded at S₅ and was found on par with S₇ and S₁₀. While, substitution level of S₉ recorded significantly shorter ear length was recorded at S₉ (8.71) over rest of substitution levels and further was found on par with S₁.

4.2.2.2 Ear weight (g) (Table 32)

Ear weight varied significantly due to nitrogen substitution with distillery effluents. Substitution level of S₅ recorded highest ear weight of 3.50 which was found significantly superior over rest of substitution levels except S₇ and S₁₀. Significantly the lowest ear weight of 3.01 was recorded at nitrogen substitution level of S₉.

4.2.2.3 Number of grains per ear (Table 32)

Grain number per ear was significantly influenced by nitrogen substitution levels. Significantly more number of grains per ear was

Table 32. Days to 50 per cent heading, ear length (cm), ear weight (g), number of grains per ear and test weight (1000-grain weight) in wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Days to 50 per cent heading			Ear length			Ear weight			Number of grains per ear			1000-grain weight		
	1999-2000			1999-2000			1999-2000			1999-2000			1999-2000		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ - 100% N substitution through liquid effluent	52.20	54.00	53.10	8.65	9.03	8.84	2.98	3.14	3.06	46.85	48.76	47.80	34.81	36.03	35.42
S ₂ - 100% N substitution through solid effluent	52.30	56.70	54.50	8.87	9.63	9.25	3.01	3.27	3.14	48.15	52.11	50.13	35.60	38.56	37.08
S ₃ - 50% N substitution through liquid effluent + 50% N substitution through solid effluent	53.40	54.40	53.90	9.04	9.18	9.11	3.06	3.12	3.09	48.72	49.48	49.10	36.21	36.79	36.50
S ₄ - 50% N substitution through liquid effluent + 50% N substitution through inorganic source	55.20	56.50	55.85	9.52	9.68	9.60	3.21	3.29	3.25	51.38	52.52	51.95	38.08	38.89	38.48
S ₅ - 50% N substitution through solid effluent + 50% N substitution through inorganic source	55.30	57.50	56.40	10.08	10.56	10.32	3.40	3.60	3.50	54.53	56.11	55.72	40.43	42.15	41.29
S ₆ - 25% N substitution through liquid effluent + 75% N substitution through inorganic source	55.10	56.70	55.90	9.56	9.80	9.68	3.22	3.33	3.27	51.52	53.08	52.30	38.30	39.32	38.81
S ₇ - 25% N substitution through solid effluent + 75% N substitution through inorganic source	55.50	57.20	56.35	10.14	10.36	10.25	3.42	3.54	3.48	54.60	56.21	55.40	40.45	41.66	41.05
S ₈ - 25% N substitution through liquid effluent + 50% N substitution through solid effluent	52.20	56.00	54.10	8.89	9.53	9.21	2.98	3.22	3.10	47.92	51.40	49.65	35.53	38.07	36.80
S ₉ - 25% N substitution through solid effluent + 75% N substitution through liquid effluent	52.70	53.10	52.90	8.69	8.73	8.71	2.99	3.03	3.01	46.95	47.25	47.10	34.90	35.06	34.98
S ₁₀ - 100% N substitution through inorganic source	56.00	56.40	56.20	10.18	10.22	10.20	3.43	3.47	3.45	54.97	55.23	55.40	40.79	40.95	40.87
S.E.m±	0.76	0.80	0.55	0.14	0.16	0.11	0.04	0.05	0.03	0.51	0.62	0.40	0.32	0.38	0.25
CD at 5%	2.26	2.37	1.58	0.41	0.47	0.31	0.12	0.15	0.09	1.51	1.84	1.15	0.95	1.13	0.72

recorded at S₅ (55.72) however was found on par with substitution levels of S₇ and S₁₀. Whereas, significantly the lowest number of grains per ear was recorded at S₉ (47.10).

4.2.2.4 Test weight (1000-grain weight) (Table 32)

Nitrogen substitution using distillery effluents had significant influence on test weight. Test weight observed was highest at S₅ (41.29) and found significantly superior over rest of substitution levels except S₇ and S₁₀. Whereas, substitution level of S₉ recorded significantly lower test weight of 34.98 as compared to other nitrogen substitution levels but was found on par with S₁.

4.2.2.5 Grain yield (q/ha) (Table 33 and Fig.9)

Grain yield of wheat differed significantly due to nitrogen substitution using distillery effluents. Significantly highest grain yield (53.14) was registered at S₅ which was found significantly superior over rest of substitution levels except S₇ and S₁₀. Significant lower grain yield (45.01) was recorded at S₉ as compared to other substitution levels except grain yield at substitution level of S₁.

4.2.2.6 Straw yield (q/ha) (Table 33 and Fig.9)

Straw yield differed significantly due to nitrogen substitution levels. The straw yield was significantly higher at nitrogen substitution level of S₅ (68.13) as compared to other substitution levels but was found on par with S₇ and S₁₀. Whereas, significantly the lowest straw yield (62.58) was recorded at S₉ which found on par with substitution level of S₁.

4.2.2.7 Harvest index (Table 33)

Harvest index (HI) showed significant variation due to nitrogen substitution by distillery effluents. Significantly higher harvest index of

Table 33. Grain yield (q/ha), straw yield (q/ha) and harvest index (HI) of wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Grain yield			Straw yield			Harvest index		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	44.79	46.37	45.58	62.30	63.64	62.97	0.418	0.421	0.419
S ₂ – 100% N substitution through solid effluent	45.69	49.51	47.60	61.75	66.76	64.25	0.425	0.426	0.425
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	46.30	47.64	46.97	62.90	64.06	63.48	0.424	0.426	0.425
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	48.98	50.06	49.52	64.16	65.40	64.78	0.432	0.433	0.432
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	52.08	54.20	53.14	66.85	69.41	68.13	0.437	0.439	0.438
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	49.23	50.64	49.93	64.32	66.28	65.30	0.433	0.433	0.433
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	52.16	53.54	52.85	67.08	69.12	68.10	0.437	0.436	0.437
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	45.70	41.02	47.36	61.41	65.87	63.54	0.426	0.427	0.426
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	44.86	45.16	45.01	62.37	62.79	62.58	0.418	0.419	0.418
S ₁₀ – 100% N substitution through inorganic source	52.48	52.74	52.61	67.58	67.92	67.75	0.437	0.437	0.437
S.E.m $\pm$	0.41	0.47	0.32	0.35	0.45	0.29	0.002	0.005	0.002
CD at 5%	1.25	1.39	0.92	1.04	1.34	0.83	0.006	0.015	0.007

LEGEND

Nitrogen Substitution levels

- S₁ - 100 per cent nitrogen substitution through liquid effluent
- S₂ - 100 per cent nitrogen substitution through solid effluent
- S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent
- S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic
- S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic
- S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic
- S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic
- S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent
- S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent
- S₁₀ - 100% nitrogen through inorganic (100:75:50 kg N:P₂O₅:K₂O/ha).

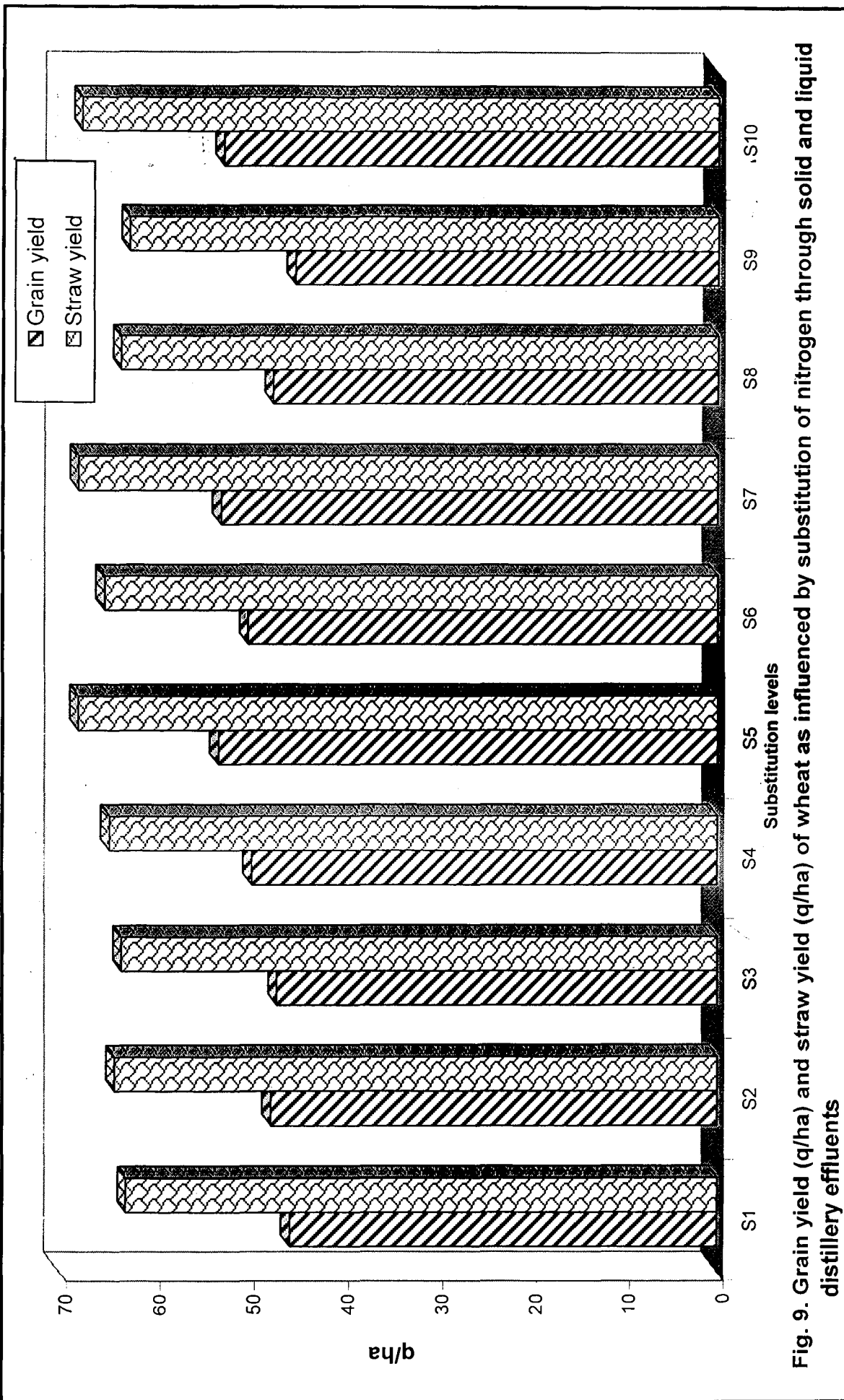


Fig. 9. Grain yield (q/ha) and straw yield (q/ha) of wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

0.438 over rest of the substitution levels of nitrogen but was found on par with S₇, S₁₀, S₆ and S₄. Significantly the lowest harvest index of 0.418 was recorded at S₉.

4.2.3 Quality parameters

4.2.3.1 Protein (%) (Table 34)

Protein content in grain differed significantly due to nitrogen substitution with distillery effluents. Substitution level of S₅ recorded significantly highest protein content (12.56) however was found on par with S₇ and S₁₀. Whereas, significantly the lowest protein content (10.91) was recorded at S₁ and was found on par with S₉, S₃ and S₈.

4.2.3.2 Sedimentation value (ml) (Table 34)

Nitrogen substitution levels brought significant influence on sedimentation value. Significant higher sedimentation value of 25.36 was recorded at S₅ over substitution levels but was found on par with nitrogen substitution levels of S₇ and S₁₀. Whereas, substitution level of S₉ recorded significantly the lowest sedimentation value (22.20) however was found on par with S₁.

4.2.3.3 Wet gluten (%) (Table 34)

Nitrogen substitution levels resulted significant variation on wet glutent content. Significantly higher wet gluten content (28.89) was recorded at S₅ as compared to other substitution levels but was found on par with S₇ and S₈. Significantly lower wet gluten (25.24) was recorded at S₉ which was again found on par with S₁.

Table 34. Protein (%), sedimentation value (ml), wet gluten (%) and dry gluten (%) in wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Protein			Sedimentation value			Wet gluten			Dry gluten		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ - 100% N substitution through liquid effluent	10.82	11.01	10.91	21.92	22.70	22.31	24.90	25.74	25.32	7.53	7.83	7.68
S ₂ - 100% N substitution through solid effluent	11.08	11.98	11.53	22.48	24.36	23.42	25.53	27.67	26.60	7.68	8.34	8.01
S ₃ - 50% N substitution through liquid effluent + 50% N substitution through solid effluent	11.05	11.19	11.12	22.25	22.61	22.43	25.31	25.73	25.52	7.84	7.95	7.89
S ₄ - 50% N substitution through liquid effluent + 50% N substitution through inorganic source	11.58	11.84	11.71	23.46	23.98	23.72	26.62	27.34	26.98	8.25	8.43	8.34
S ₅ - 50% N substitution through solid effluent + 50% N substitution through inorganic source	12.28	12.84	12.56	24.82	25.90	25.36	28.21	29.57	28.89	8.74	9.18	8.96
S ₆ - 25% N substitution through liquid effluent + 75% N substitution through inorganic source	11.63	11.97	11.80	23.55	24.05	23.80	26.65	27.46	27.05	8.28	8.52	8.40
S ₇ - 25% N substitution through solid effluent + 75% N substitution through inorganic source	12.30	12.66	12.48	24.85	25.51	25.18	23.25	29.05	28.65	8.75	9.03	8.89
S ₈ - 25% N substitution through liquid effluent + 50% N substitution through solid effluent	10.83	11.59	11.21	21.82	23.40	22.61	24.83	26.61	25.72	7.69	8.23	7.96
S ₉ - 25% N substitution through solid effluent + 75% N substitution through liquid effluent	10.95	11.01	10.98	22.16	22.25	22.20	25.20	25.28	25.24	7.54	7.62	7.58
S ₁₀ - 100% N substitution through inorganic source	12.40	12.44	12.42	24.98	25.12	25.05	28.44	28.56	28.50	8.84	8.86	8.85
S.E.m±	0.14	0.17	0.11	0.48	0.54	0.36	0.56	0.59	0.41	0.17	0.19	0.13
CD at 5%	0.41	0.50	0.31	1.42	1.60	1.03	1.66	1.75	1.18	0.50	0.56	0.36

4.2.3.4 Dry gluten (%) (Table 34)

Dry gluten in wheat grain showed significant variation due to nitrogen substitution levels. Substitution level of S₅ recorded significantly higher dry gluten of 8.96 as compared to other nitrogen substitution levels except S₇ and S₈. Whereas significantly lower dry gluten of 7.58 was recorded at S₉ over other substitution levels but was found on par with S₁ and S₃.

4.2.4 Nutrient contents in plant

4.2.4.1 Nutrient contents in plant at anthesis

4.2.4.1.1 Nitrogen (%) (Table 35)

Nitrogen content varied significantly due to substitution levels of nitrogen by distillery effluents. Substitution level of S₅ recorded highest nitrogen content (2.36) which found significantly superior over rest of substitution levels except S₇ and S₁₀. Significantly lower nitrogen content was recorded at S₉.

4.2.4.1.2 Phosphorus (%) (Table 35)

Nitrogen substitution levels did not differ significantly for phosphorus content in plant at anthesis.

4.2.4.1.3 Potassium (%) (Table 35)

Potassium content in plant varied significantly due to nitrogen substitution levels using distillery effluents. Significantly higher potassium content in plant at anthesis was recorded at S₁ (2.90) over other substitution levels and was found on par with S₃, S₈, S₂ and S₉. Whereas, significantly lowest potassium content was recorded at S₁₀ (2.81).

Table 35. Nitrogen, phosphorus and potassium contents (%) in wheat at anthesis as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Nitrogen			Phosphorus			Potassium		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	2.02	2.06	2.04	0.201	0.204	0.202	2.89	2.91	2.90
S ₂ – 100% N substitution through solid effluent	2.04	2.23	2.13	0.201	0.205	0.203	2.86	2.90	2.88
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	2.09	2.12	2.10	0.200	0.204	0.202	2.87	2.91	2.89
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	2.19	2.23	2.21	0.199	0.203	0.201	2.83	2.85	2.84
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	2.31	2.40	2.36	0.19	0.202	0.199	2.82	2.84	2.83
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	2.20	2.24	2.22	0.196	0.201	0.198	2.81	2.84	2.82
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	2.32	2.38	2.35	0.197	0.201	0.199	2.81	2.83	2.82
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	2.04	2.20	2.12	0.201	0.205	0.203	2.86	2.91	2.89
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	2.02	2.04	2.03	0.201	0.203	0.202	2.87	2.89	2.88
S ₁₀ – 100% N substitution through inorganic source	2.33	2.35	2.34	0.196	0.198	0.197	2.80	2.82	2.81
S.E.m±	0.05	0.05	0.03	0.003	0.005	0.003	0.006	0.007	0.005
CD at 5%	0.15	0.15	0.10	NS	NS	NS	0.018	0.020	0.013

NS – Non significant

4.2.4.2 Nutrient contents in grain and straw and total uptake at harvest

4.2.4.2.1 Nitrogen contents (%) in grain and straw and total nitrogen uptake (kg/ha) (Table 36 and Fig.10)

Nitrogen contents in grain and stover differed significantly due to nitrogen substitution levels. Significantly higher nitrogen contents in grain (2.01) and straw (0.569) were recorded at S₅ over other substitution levels but was found on par with S₇ and S₁₀.

The total uptake of nitrogen by crop showed significant variation due to nitrogen substitution levels. Significantly higher total nitrogen uptake of 145.37 was recorded at S₅ over other substitution level and was found on par with S₇ and S₁₀. While, significantly the lowest total nitrogen uptake (109.09) was recorded at S₉.

4.2.4.2.2 Phosphorus contents (%) in grain and straw and total phosphorus uptake (kg/ha) (Table 37 and Fig.10)

Substitution of nitrogen using distillery effluents did not influence significantly on phosphorus content in grain and straw. However, total phosphorus uptake differed significantly due to nitrogen substitution levels. Significantly highest total phosphorus uptake (43.84) was recorded at S₅ which was found on par with S₇ and S₈. Whereas, substitution levels of S₉ recorded significantly the lowest total phosphorus uptake of 38.89.

4.2.4.2.3 Potassium contents (%) in grain and straw and total potassium uptake (kg/ha) (Table 38 and Fig.10)

Potassium contents in grain showed significant variation due to substitution levels. Substitution level of S₁ recorded significantly higher

Table 36. Nitrogen contents (%) in grain and straw and total nitrogen uptake (kg/ha) by wheat at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Nitrogen content						Total uptake		
	Grain			Straw					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	1.73	1.76	1.74	0.476	0.494	0.485	107.14	113.05	110.09
S ₂ – 100% N substitution through solid effluent	1.77	1.92	1.84	0.491	0.527	0.507	111.19	130.24	120.71
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	1.77	1.79	1.78	0.501	0.504	0.502	113.46	117.56	115.51
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	1.85	1.89	1.87	0.524	0.536	0.530	124.23	129.66	126.94
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	1.96	2.05	2.01	0.556	0.582	0.569	139.24	151.50	145.37
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	1.86	1.91	1.88	0.527	0.541	0.534	125.47	132.58	129.02
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	1.97	2.02	1.99	0.559	0.575	0.567	140.25	147.89	144.07
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	1.73	1.85	1.79	0.545	0.583	0.564	112.53	129.08	120.08
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	1.75	1.76	1.75	0.480	0.482	0.481	108.44	109.74	109.09
S ₁₀ – 100% N substitution through inorganic source	1.98	1.99	1.99	0.561	0.563	0.562	141.83	143.19	142.51
S.E.m±	0.05	0.06	0.04	0.008	0.009	0.006	1.36	1.66	1.07
CD at 5%	0.15	0.18	0.11	0.024	0.027	0.017	4.04	4.93	3.06

Table 37. Phosphorus contents (%) in grain and straw and total phosphorus uptake (kg/ha) by wheat at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Phosphorus content						Total uptake		
	Grain			Straw			1999-2000	2000-2001	Pooled
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled			
S ₁ – 100% N substitution through liquid effluent	0.598	0.618	0.608	0.178	0.181	0.179	37.87	40.18	39.02
S ₂ – 100% N substitution through solid effluent	0.593	0.643	0.618	0.176	0.186	0.181	37.96	44.25	41.10
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	0.606	0.614	0.610	0.177	0.179	0.178	39.19	40.67	39.93
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	0.594	0.608	0.601	0.175	0.179	0.177	40.32	42.15	41.23
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	0.587	0.611	0.599	0.172	0.180	0.176	42.07	45.61	43.84
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	0.593	0.612	0.602	0.175	0.181	0.178	40.45	42.98	41.71
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	0.589	0.605	0.597	0.173	0.177	0.175	42.32	44.62	43.47
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	0.591	0.633	0.612	0.172	0.184	0.178	37.74	40.71	39.22
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	0.612	0.616	0.614	0.179	0.181	0.180	38.61	39.18	38.89
S ₁₀ – 100% N substitution through inorganic source	0.594	0.597	0.595	0.174	0.176	0.175	42.93	43.43	43.18
S.E.m±	0.011	0.014	0.009	0.005	0.006	0.004	0.88	0.95	0.65
CD at 5%	NS	NS	NS	NS	NS	NS	2.61	2.95	1.86

NS – Non significant

Table 38. Potassium contents (%) in grain and straw and total potassium uptake (kg/ha) by wheat at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Potassium content						Total uptake		
	Grain			Straw			1999-2000	2000-2001	Pooled
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled			
S ₁ – 100% N substitution through liquid effluent	0.343	0.355	0.349	1.13	1.17	1.15	85.58	90.73	88.15
S ₂ – 100% N substitution through solid effluent	0.334	0.362	0.348	1.12	1.20	1.16	84.42	98.03	91.22
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	0.340	0.346	0.343	1.14	1.16	1.15	87.45	90.79	89.12
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	0.334	0.342	0.338	1.15	1.17	1.16	90.14	93.64	91.89
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	0.328	0.342	0.335	1.12	1.16	1.14	91.95	99.05	95.50
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	0.332	0.342	0.337	1.18	1.22	1.13	92.24	98.18	95.21
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	0.329	0.338	0.334	1.11	1.15	1.13	91.62	97.59	94.60
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	0.330	0.354	0.342	1.11	1.19	1.15	83.25	95.73	89.49
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	0.340	0.341	0.340	1.15	1.16	1.16	86.97	88.24	87.60
S ₁₀ – 100% N substitution through inorganic source	0.328	0.331	0.329	1.10	1.11	1.11	91.55	92.85	92.20
S.E.m±	0.005	0.006	0.004	0.03	0.03	0.02	2.36	2.40	1.68
CD at 5%	0.015	0.018	0.011	NS	NS	NS	7.01	7.13	4.82

NS – Non significant

LEGEND

Nitrogen Substitution levels

- S₁ - 100 per cent nitrogen substitution through liquid effluent
- S₂ - 100 per cent nitrogen substitution through solid effluent
- S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent
- S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic
- S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic
- S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic
- S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic
- S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent
- S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent
- S₁₀ - 100% nitrogen through inorganic (100:75:50 kg N:P₂O₅:K₂O/ha).

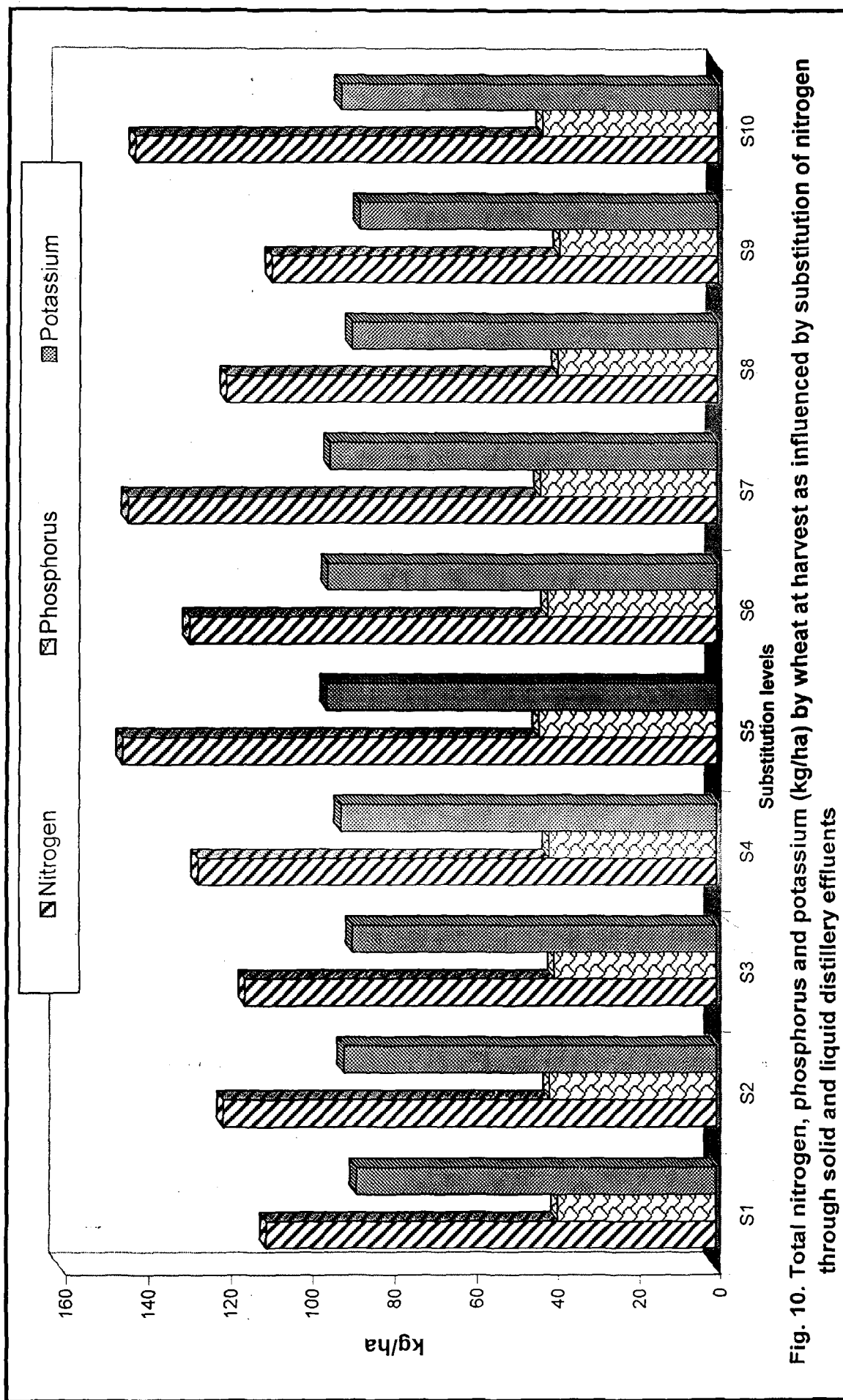


Fig. 10. Total nitrogen, phosphorus and potassium (kg/ha) by wheat at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

potassium content (0.349) as compared to other substitution however was found on par with S₂, S₃, S₈, S₉ and S₄. Whereas, S₁₀ recorded significantly lowest potassium content in grain (0.329). However, potassium content in straw did not differ significantly due to substitution levels.

Nitrogen substitution levels influenced significantly on total potassium uptake. Significantly higher total uptake (95.50) was recorded at S₅ over other substitution levels and was found on par with S₆, S₇, S₁₀, S₄ and S₂. Whereas, significantly the lowest total potassium uptake was recorded at S₉ (87.60).

4.2.4.2.4 Zinc contents (ppm) in grain and straw and total zinc uptake (kg/ha) (Table 39)

Zinc contents in grain and stover was not differed significantly due substitution levels. However, there was significant variation on total uptake. Significantly higher total zinc uptake (0.296) was recorded at S₅ as compared to other substitution levels but was found on par with S₇ and S₁₀. Significantly the lowest total uptake was recorded at S₉ (0.268) however was found par with S₁ and S₃.

4.2.4.2.5 Copper contents (ppm) in grain and straw and total copper uptake (kg/ha) (Table 39)

Nitrogen substitution levels had no significant influence on copper contents in grain and stover. However, total copper uptake was influenced significantly by nitrogen substitution levels. Significantly higher total copper uptake of 0.248 was recorded at S₅ as compared to other substitution levels and was found on par with S₇ and S₁₀.

Substitution level of S₉ recorded significantly the lowest total copper uptake (0.223) however was found on par with S₁, S₃, S₈ and S₄.

4.2.4.2.6 Iron contents (ppm) in grain and straw and total iron uptake (kg/ha) (Table 40)

Iron contents in grain and straw was not influenced significantly by nitrogen substitution levels. Whereas, total iron uptake showed significant influence. The highest iron uptake was recorded at S₅ (2.46) which was found superior over other substitution levels but was found on par with S₇, S₁₀, S₆ and S₄. Whereas, significantly the lowest total iron uptake was recorded at S₉ (2.20).

4.2.4.2.7 Manganese contents (ppm) in grain and straw and total manganese uptake (kg/ha) (Table 40)

The nitrogen substitution levels using distillery effluents could not bring significant influence on manganese content in grain and straw. While, total uptake were differed significantly due substitution levels. Significantly the highest total uptake of 0.986 was recorded at S₅ further was found on par with S₇ and S₁₀. Significantly lower total uptake (0.893) was recorded at S₉ as compared to other substitution levels but was found on par with S₁.

4.2.5 Physico-chemical properties of soil

4.2.5.1 Physical properties

4.2.5.1.1 Bulk density (Mg/m³) (Table 41)

Bulk density of soil did not vary significantly due to nitrogen substitution levels.

Table 40. Iron and manganese contents (ppm) in grain and straw and total iron and manganese uptake (kg/ha) by wheat at harvest as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Iron						Manganese						Total uptake					
	Iron content			Total uptake			Manganese content			Total uptake								
	Grain		Straw	Pooled		1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Grain	Pooled			1999-2000	2000-2001		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Grain	Pooled	1999-2000	2000-2001			
S ₁ – 100% N substitution through liquid effluent	181.37	181.83	181.60	221.69	221.87	221.78	2.19	2.26	2.22	50.96	52.74	51.85	105.92	107.48	106.70	0.888	0.928	Pooled
S ₂ – 100% N substitution through solid effluent	181.36	181.78	181.57	221.72	221.93	221.82	2.20	2.38	2.29	50.85	52.98	51.92	105.01	108.41	106.71	0.880	0.986	Pooled
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	181.37	181.43	181.40	221.64	221.70	221.67	2.23	2.28	2.25	50.64	52.86	51.75	104.81	108.19	106.50	0.893	0.945	Pooled
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	181.17	181.19	181.18	221.20	221.41	221.30	2.31	2.35	2.33	50.40	51.52	50.96	103.78	106.02	104.86	0.913	0.951	Pooled
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	181.20	181.26	181.23	221.36	221.54	221.45	2.41	2.52	2.46	50.09	51.93	51.01	103.85	106.11	104.98	0.955	1.017	Pooled
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	181.02	181.18	181.10	220.98	221.28	221.13	2.31	2.38	2.34	49.95	51.39	50.67	103.78	104.79	104.28	0.913	0.954	Pooled
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	181.05	181.25	181.15	221.13	221.39	221.26	2.43	2.50	2.46	50.13	50.64	50.88	103.80	105.70	104.75	0.957	1.001	Pooled
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	181.35	181.77	181.56	221.71	221.92	221.31	2.19	2.35	2.27	50.64	52.28	51.46	105.21	106.59	105.90	0.877	0.958	Pooled
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	181.32	181.76	181.54	221.68	221.92	221.80	2.19	2.21	2.20	51.26	51.52	56.39	105.50	106.02	105.76	0.888	0.899	Pooled
S ₁₀ – 100% N substitution through inorganic source	180.78	180.86	180.82	220.59	220.73	220.66	2.44	2.45	2.44	49.93	50.33	50.13	102.72	103.48	103.10	0.956	0.968	Pooled
S Em±	0.62	0.79	0.50	0.56	0.61	0.42	0.04	0.10	0.05	0.82	0.97	0.63	1.75	1.84	1.27	0.011	0.013	Pooled
CD at 5%	NS	NS	NS	NS	NS	NS	0.12	0.29	0.14	NS	NS	NS	NS	NS	NS	0.033	0.038	Pooled

NS - Non significant

4.2.5.2 Chemical properties

4.2.5.2.1 Soil reaction (pH) (Table 41)

The substitution of nitrogen by distillery effluents did not influence significantly on soil reaction.

4.2.5.2.2 Electrical conductivity (dSm^{-1}) (Table 41)

The nitrogen substitution levels exhibited significant influence on electrical conductivity of soil. Significantly highest electrical conductivity was recorded at S_1 (0.63) which was found on par with all substitution levels except S_{10} .

4.2.5.2.3 Organic carbon (%) (Table 41)

Organic carbon content of soil was not influenced significantly by nitrogen substitution levels.

4.2.5.2.4 Nutrient contents in soil

4.2.5.2.4.1 Available nitrogen (kg/ha) (Table 42 and Fig.11)

Available nitrogen of soil varied significantly due to substitution levels. Significantly higher available nitrogen was recorded at S_9 (252.56) over rest of substitution levels but was found on par with S_1 , S_3 , S_8 and S_2 . Whereas, significantly the lowest available nitrogen was recorded at S_5 (226.83) which was found on par with S_7 , S_{10} , S_6 and S_4 .

4.2.5.2.4.2 Available phosphorus (kg/ha) (Table 42 and Fig.11)

The substitution levels of nitrogen by distillery effluents brought significant influence on available phosphorus content of soil. Substitution level of S_5 recorded significantly higher available phosphorus (32.12) at S_2 as compared to other substitution levels and

Table 41. Bulk density (Mg/m^3), soil reaction (pH), electrical conductivity (EC, dSm^{-1}) and organic carbon (OC, %) in soil after harvest of wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Bulk density			pH			EC			OC		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	1.51	1.50	1.51	7.16	7.19	7.17	0.60	0.64	0.63	0.49	0.50	0.49
S ₂ – 100% N substitution through solid effluent	1.50	1.49	1.49	7.13	7.12	7.12	0.59	0.60	0.54	0.50	0.53	0.51
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	1.51	1.50	1.50	7.13	7.15	7.14	0.56	0.58	0.57	0.49	0.52	0.50
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	1.52	1.50	1.51	7.15	7.16	7.15	0.54	0.55	0.54	0.49	0.50	0.49
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	1.51	1.49	1.50	7.11	7.13	7.12	0.54	0.55	0.54	0.50	0.53	0.51
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	1.52	1.51	1.51	7.12	7.10	7.11	0.56	0.57	0.56	0.49	0.50	0.49
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	1.52	1.50	1.51	7.14	7.15	7.14	0.55	0.56	0.55	0.49	0.52	0.50
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	1.50	1.48	1.49	7.13	7.14	7.13	0.58	0.60	0.59	0.50	0.51	0.50
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	1.51	1.49	1.50	7.15	7.16	7.15	0.59	0.64	0.61	0.49	0.51	0.50
S ₁₀ – 100% N substitution through inorganic source	1.52	1.52	1.52	7.11	7.10	7.10	0.45	0.49	0.47	0.48	0.47	0.47
S.E.m.	0.06	0.05	0.04	0.03	0.04	0.02	0.04	0.05	0.03	0.03	0.04	0.02
CD at 5%	NS	NS	NS	NS	NS	NS	0.12	0.15	0.09	NS	NS	NS

NS – Non significant

Table 42. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Available nitrogen			Available phosphorus			Available potassium		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	248.35	253.43	250.89	31.31	32.79	32.05	532.50	539.36	535.93
S ₂ – 100% N substitution through solid effluent	244.84	249.36	245.10	31.42	32.83	32.12	511.25	517.31	514.28
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	242.55	255.17	248.86	31.36	32.80	32.08	521.03	526.01	523.52
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	234.47	237.25	235.86	29.61	30.02	29.81	460.48	464.64	462.56
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	225.43	232.23	226.83	29.70	30.15	29.93	455.36	456.24	456.80
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	233.70	236.20	234.95	29.38	30.06	29.72	442.47	447.55	445.01
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	227.50	230.22	228.86	29.45	30.13	29.79	442.15	443.25	442.70
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	243.82	252.74	247.28	31.38	32.64	32.01	519.63	524.09	521.86
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	250.87	254.93	252.56	31.10	31.32	31.87	527.17	531.73	529.45
S ₁₀ – 100% N substitution through inorganic source	230.86	221.64	230.25	29.27	29.31	29.29	365.52	364.56	365.04
S.E.m±	5.16	6.09	3.98	0.35	0.44	0.28	8.60	9.27	6.32
CD at 5%	15.32	18.09	11.42	1.04	1.31	0.80	25.54	27.53	18.14

LEGEND

Nitrogen Substitution levels

- S₁ - 100 per cent nitrogen substitution through liquid effluent
- S₂ - 100 per cent nitrogen substitution through solid effluent
- S₃ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through solid effluent
- S₄ - 50 per cent nitrogen through liquid effluent + 50 per cent nitrogen through inorganic
- S₅ - 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic
- S₆ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through inorganic
- S₇ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic
- S₈ - 25 per cent nitrogen through liquid effluent + 75 per cent nitrogen through solid effluent
- S₉ - 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent
- S₁₀ - 100% nitrogen through inorganic (100:75:50 kg N:P₂O₅:K₂O/ha).

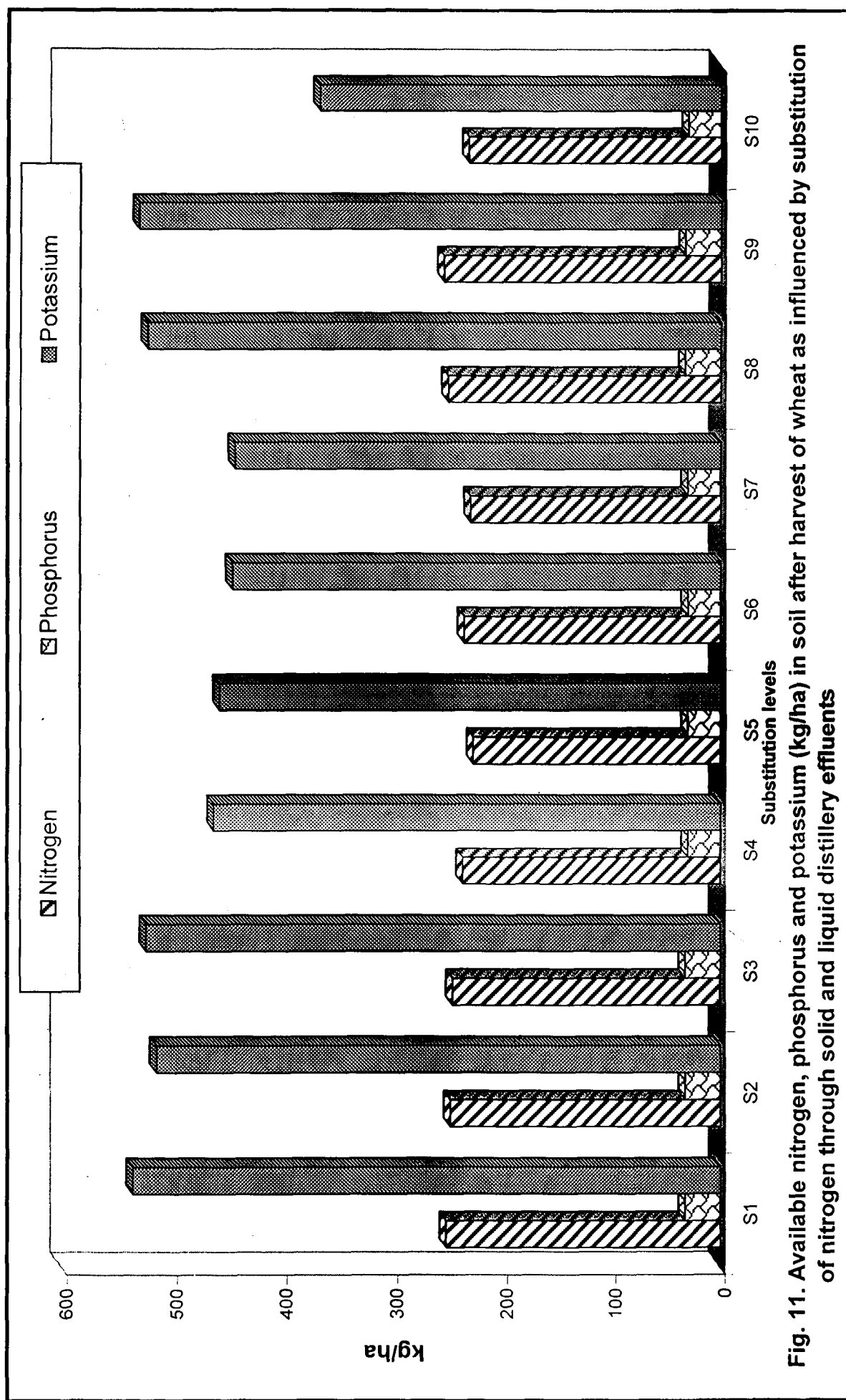


Fig. 11. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

was found on par with S₃, S₁, S₈ and S₉. Significantly the lowest available phosphorus in soil was recorded at S₁₀ (29.29).

4.2.5.2.4.3 Available potassium (kg/ha) (Table 42 and Fig.11)

Available potassium was influenced significantly by substitution levels. Significantly higher available potassium in soil was recorded at S₁ (535.93) over other substitution levels and was found on par with S₉, S₃ and S₈. Significantly the lowest available potassium was recorded at S₁₀ (365.04).

4.2.5.2.4.4 DTPA extractable (available) micronutrients in soil (ppm) (Table 43)

4.2.5.2.4.4.1 Zinc

Zinc content in soil was not influenced significantly by application of distillery effluents as a source of nitrogen. However, higher values of zinc content in soil were observed with 100 per cent substitution through solid and liquid effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

4.2.5.2.4.4.2 Copper

Substitution of nitrogen with distillery effluents did not vary significantly for copper content in soil. Though values of copper were nonsignificant, higher values were observed with 100 per cent substitution through solid and liquid effluent either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

4.2.5.2.4.4.3 Iron

Substitution levels had no significant influence on iron content in soil. But the higher values were observed with nitrogen substitution

Table 43. DTPA extractable zinc, copper, iron and manganese contents (ppm) in soil after harvest of wheat as influenced by substitution of nitrogen through solid and liquid distillery effluents

Nitrogen substitution level	Zn			Cu			Fe			Mn		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	2.16	2.20	2.18	1.82	1.84	1.83	5.20	5.24	5.22	9.05	9.11	9.08
S ₂ – 100% N substitution through solid effluent	2.14	2.23	2.19	1.80	1.86	1.83	5.16	5.30	5.23	9.06	9.14	9.10
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	2.14	2.16	2.15	1.80	1.83	1.81	5.20	5.24	5.22	9.03	9.09	9.06
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	2.16	2.20	2.18	1.80	1.84	1.82	4.97	5.06	5.01	8.85	8.97	8.91
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	2.13	2.19	2.16	1.79	1.83	1.81	5.08	5.18	5.13	8.87	8.96	8.92
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	2.13	2.17	2.15	1.79	1.81	1.80	4.96	5.01	4.98	8.78	8.84	8.81
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	2.07	2.11	2.0	1.74	1.76	1.75	5.07	5.11	5.09	8.84	8.90	8.87
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	2.15	2.24	2.20	1.79	1.87	1.83	5.16	5.26	5.21	8.95	9.07	9.01
S ₉ – 25% N substitution through solid effluent + 75% N substitution through liquid effluent	2.16	2.18	2.17	1.81	1.83	1.82	5.18	5.23	5.20	9.01	9.04	9.02
S ₁₀ – 100% N substitution through inorganic source	2.08	2.07	2.08	1.74	1.72	1.74	4.96	4.90	4.92	8.78	8.74	8.76
S.E.m±	0.09	0.10	0.07	0.03	0.04	0.03	0.16	0.15	0.11	0.20	0.22	0.15
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

NS – Non significant

through 100 per cent solid and liquid distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

4.2.5.2.4.4 Manganese

Manganese content in soil was not influenced significantly by substitution of nitrogen by distillery effluent. Though the values were nonsignificant higher values were seen at 100 per nitrogen substitution through solid and liquid distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

4.2.6 Economics (Rs./ha) (Table 44)

The nitrogen substitution level of S₅ recorded the maximum gross income (46,600) which was found on par with S₁₀, S₆ and S₄ and the lowest gross income of 39,763 was recorded with S₉. The maximum net returns and the highest benefit:cost ratio were obtained again with S₅ (34,806 and 2.95) and was closely followed by S₇ (34,471 and 2.90) and S₁₀ (34,461 and 2.95). Whereas, the lowest net return and benefit:cost ratio were noticed in S₉ (28,581 and 2.55) followed by S₁ (29,062 and 2.60).

4.3 Experiment 3 : Studies on the performance of *rabi* maize against graded dilution of liquid distillery effluent as a source of irrigation

4.3.1 Growth parameters

4.3.1.1 Plant height (cm) (Table 45)

Plant height differed significantly due to dilution levels at all the crop growth stages. Significantly taller plants were noticed at 1:5 dilution level (20.34, 139.08, 203.90 and 211.71 at 30, 60, 90 days after

Table 44. Economics as influenced by nitrogen substitution through solid and liquid distillery effluents in wheat

Nitrogen substitution level	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)			Net returns (Rs./ ha)			B:C ratio		
		1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
S ₁ – 100% N substitution through liquid effluent	11180	39570	40914	40242	28390	29734	29062	2.54	2.66	2.60
S ₂ – 100% N substitution through solid effluent	11242	40257	43614	41935	29015	32372	30693	2.58	2.88	2.73
S ₃ – 50% N substitution through liquid effluent + 50% N substitution through solid effluent	11186	40814	41956	41385	29628	30770	30198	2.65	2.75	2.70
S ₄ – 50% N substitution through liquid effluent + 50% N substitution through inorganic source	11561	43033	43972	43506	31472	32411	32002	2.72	2.80	2.76
S ₅ – 50% N substitution through solid effluent + 50% N substitution through inorganic source	11794	45675	47525	46600	33881	35731	34806	2.87	3.03	2.95
S ₆ – 25% N substitution through liquid effluent + 75% N substitution through inorganic source	11805	43243	44489	43862	31438	32684	32057	2.66	2.77	2.71
S ₇ – 25% N substitution through solid effluent + 75% N substitution through inorganic source	11895	45753	46975	46366	33858	35080	34471	2.85	2.95	2.90
S ₈ – 25% N substitution through liquid effluent + 50% N substitution through solid effluent	11190	40245	43168	41706	29055	31978	30516	2.50	2.86	2.73
S ₉ – 25% N substitution through solid effluent + 75% N substitution through 33343 liquid effluent	11182	39630	39895	39763	28448	28713	28581	2.54	2.56	2.55
S ₁₀ – 100% 822N substitution through inorganic 2441 source	11692	46039	46267	46153	34347	34575	34461	2.94	2.96	2.95
S.E.m±		1598	1678	1130	1015	1111	752	0.07	0.08	0.06
CD at 5%		4508	4984	3243	3015	3301	2158	0.21	0.24	0.17

Table 45. Plant height (cm) at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	20.05	20.63	20.34	138.27	139.90	139.08	202.12	205.68	203.90	207.78	215.65	211.70
D ₂ – 1:10 (liquid effluent : good water)	19.04	20.24	20.04	135.85	137.60	136.72	196.90	198.08	197.49	203.63	207.70	205.66
D ₃ – 1:25 (liquid effluent : good water)	19.50	19.83	19.67	134.60	135.13	134.87	192.60	197.17	194.88	201.40	202.05	201.72
D ₄ – 1:50 (liquid effluent : good water)	19.32	19.50	19.41	130.20	132.07	131.13	192.40	193.50	192.95	198.65	199.05	198.85
D ₅ – Undiluted liquid effluent	14.05	14.29	14.17	91.80	93.60	92.70	130.50	134.00	132.25	116.90	119.56	118.23
D ₆ – Good water	19.28	14.49	19.38	127.33	129.20	128.27	188.83	190.50	189.66	194.38	195.70	195.04
S.E.m±	0.55	0.64	0.42	0.99	2.54	1.25	3.45	3.96	2.62	3.61	3.97	2.68
CD at 5%	1.71	1.99	1.24	3.08	7.89	3.68	10.73	12.31	7.73	11.23	12.35	7.91

DAS – Days after sowing

sowing (DAS) and at harvest, respectively) however it was found on par with dilution level of 1:10. Whereas, significantly the shortest plants were recorded with irrigation by undiluted effluent at all the crop growth stages (14.17, 92.70, 132.25 and 118.23 at 30, 60, 90 DAS and at harvest, respectively).

4.3.1.2 Number of green leaves per plant (Table 46)

Green leaves per plant increased upto 60 DAS and thereafter showed declining trend. There was no significant difference on number of leaves per plant due to dilution levels at all the crop growth stages.

4.3.1.3 Leaf area per plant (dm² /plant) (Table 47)

The dilution levels brought significant influence on leaf area per plant at all the growth stages. The lower dilution level of 1:5 recorded significantly higher leaf area over rest of the dilution levels at all the growth stages (7.67, 88.31, 78.10, 35.32 at 30, 60, 90 DAS and at harvest, respectively) and was found on par with 1:10 dilution level. Significantly the lowest leaf area was recorded with irrigation by undiluted effluent (5.05, 63.62, 41.05 and 17.42 at 30, 60, 90 DAS and at harvest, respectively).

4.3.1.4 Leaf area index (Table 48)

At all the growth stages, leaf area index (LAI) differed significantly due to dilution levels. Highest LAI was recorded at 1:5 dilution level and was found on par with dilution level of 1:10. Significantly the lowest leaf area index was recorded with irrigation by undiluted effluent irrespective of all the growth stages.

Table 46. Number of green leaves at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	6.52	6.85	6.68	13.91	13.96	13.93	11.67	11.85	11.76	4.77	4.92	4.84
D ₂ – 1:10 (liquid effluent : good water)	6.60	6.66	6.63	13.57	13.80	13.68	11.30	11.52	11.41	4.68	4.93	4.80
D ₃ – 1:25 (liquid effluent : good water)	6.55	6.70	6.62	13.42	13.50	13.46	11.20	11.37	11.28	4.69	4.72	4.70
D ₄ – 1:50 (liquid effluent : good water)	6.42	6.58	6.50	13.30	13.40	13.35	11.15	11.22	11.18	4.56	4.60	4.58
D ₅ – Undiluted liquid effluent	6.35	6.37	6.36	13.09	13.21	13.10	10.96	11.07	11.01	3.22	3.79	3.50
D ₆ – Good water	6.42	6.50	6.46	13.16	13.30	13.23	11.10	11.16	11.13	4.42	4.58	4.50
S.Em±	0.18	0.14	0.12	0.40	0.50	0.32	0.25	0.33	0.20	0.20	0.22	0.15
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.62	0.68	NS

DAS – Days after sowing

NS – Non significant

Table 47. Leaf area (dm^2/plant) at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	7.60	7.75	7.67	87.48	89.14	88.31	77.30	78.90	78.10	34.90	36.14	35.32
D ₂ – 1:10 (liquid effluent : good water)	7.25	7.41	7.33	83.70	85.42	84.56	75.97	77.43	76.70	33.50	34.82	34.16
D ₃ – 1:25 (liquid effluent : good water)	6.75	6.89	6.82	78.65	80.55	79.60	71.27	73.03	72.15	31.95	33.72	32.33
D ₄ – 1:50 (liquid effluent : good water)	6.74	6.84	6.79	77.50	78.85	78.17	68.63	69.75	69.19	30.48	30.90	30.69
D ₅ – Undiluted liquid effluent	4.96	5.14	5.05	63.09	64.15	63.62	40.65	41.45	41.05	17.20	17.64	17.42
D ₆ – Good water	6.54	6.62	6.56	75.30	76.20	75.75	67.94	68.73	68.33	29.93	30.39	30.16
S.E.m $\pm$	0.22	0.26	0.17	1.27	2.01	1.37	1.14	1.45	0.92	0.66	0.78	0.51
CD at 5%	0.68	0.81	0.50	3.95	6.25	4.04	3.54	4.51	2.71	2.05	2.43	1.50

DAS – Days after sowing

Table 48. Leaf area index (LAI) at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	0.422	0.430	0.426	4.86	4.94	4.90	4.29	4.39	4.34	1.94	2.01	1.97
D ₂ – 1:10 (liquid effluent : good water)	0.403	0.417	0.410	4.65	4.75	4.70	4.22	4.30	4.26	1.86	1.93	1.89
D ₃ – 1:25 (liquid effluent : good water)	0.375	0.383	0.379	4.37	4.47	4.42	3.96	4.06	4.01	1.77	1.87	1.82
D ₄ – 1:50 (liquid effluent : good water)	0.374	0.380	0.377	4.30	4.38	4.34	3.81	3.87	3.84	1.69	1.72	1.70
D ₅ – Undiluted liquid effluent	0.275	0.285	0.280	3.50	3.56	3.53	2.26	2.30	2.28	0.95	0.98	0.97
D ₆ – Good water	0.363	0.367	0.365	4.18	4.24	4.21	3.77	3.82	3.79	1.66	1.69	1.67
S.E.m±	0.008	0.009	0.006	0.10	0.11	0.07	0.06	0.08	0.05	0.04	0.04	0.03
CD at 5%	0.025	0.028	0.018	0.31	0.34	0.21	0.19	0.25	0.15	0.12	0.12	0.09

DAS – Days after sowing

4.3.1.5 Leaf area duration (days) (Table 49)

Leaf area duration (LAD) differed significantly due to dilution levels at all the growth stages. Highest LAD of 79.89 at 30-60 DAS, 138.60 at 60-90 DAS and 94.72 at 90 DAS-harvest were recorded at lower dilution level of 1:5. Whereas, irrigation by undiluted effluent registered significantly the lowest LAD at all the growth stages (57.14 at 30-60 DAS, 87.15 at 60-90 DAS and 48.71 at 90 DAS-harvest).

4.3.1.6 Dry matter production and its accumulation

4.3.1.6.1 Total dry matter production (g/plant) (Table 50)

Significant difference in total dry matter (TDM) production was found due to dilution levels at all the growth stages. There was progressive increase in TDM production with age of the crop. Irrigation with dilution level of 1:5 recorded significantly higher TDM over rest of the dilution levels at all the growth stages (9.05, 83.55, 254.01 and 355.99 at 30, 60, 90 DAS and at harvest, respectively) but was found on par with 1:10 dilution level. Whereas, significantly the lowest TDM of 6.69 at 30 DAS, 40.71 at 60 DAS, 121.78 at 90 DAS and 152.93 at harvest were recorded at irrigation by undiluted effluent.

4.3.1.6.2 Dry matter accumulation in leaves (g/plant) (Table 51)

Dilution levels influenced dry matter accumulation (DMA) in leaves significantly at all the crop growth stages. Irrigation by dilution level of 1:5 at all the growth stages registered significantly higher DMA in leaves over rest of dilution levels and irrigation by undiluted effluent recorded significantly the lowest DMA in leaf (3.65, 20.95, 24.35 and 24.91 at 30, 60, 90 DAS and at harvest, respectively).

Table 49. Leaf area duration (days) at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30-60 DAS			60-90 DAS			90 DAS-Harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	79.23	80.55	79.89	137.25	139.95	138.60	93.45	96.00	94.72
D ₂ – 1:10 (liquid effluent : good water)	75.79	77.50	76.64	133.05	135.75	134.40	91.20	93.45	92.32
D ₃ – 1:25 (liquid effluent : good water)	71.17	72.79	71.98	124.95	127.95	126.45	85.95	88.95	87.45
D ₄ – 1:50 (liquid effluent : good water)	70.11	71.40	70.75	121.65	123.75	122.70	82.50	83.85	83.17
D ₅ –Undiluted liquid effluent	56.62	57.67	57.14	86.40	87.90	87.15	48.22	49.20	48.71
D ₆ – Good water	68.14	69.10	68.62	119.25	120.90	120.07	81.45	82.65	72.05
S.E.m±	1.50	1.68	1.12	2.45	3.02	1.93	1.10	1.32	0.86
CD at 5%	4.66	5.22	3.30	7.62	9.39	5.69	3.42	4.10	2.54

Table 50. Total dry matter production (g/plant) at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	8.93	9.18	9.05	83.19	83.92	83.55	250.77	257.25	254.01	352.43	359.56	355.99
D ₂ – 1:10 (liquid effluent : good water)	8.68	8.95	8.81	81.04	81.97	81.50	244.79	250.60	247.69	344.32	351.96	348.14
D ₃ – 1:25 ((liquid effluent : good water)	8.26	8.38	8.32	75.11	75.36	75.23	232.08	235.86	233.97	327.12	332.37	329.74
D ₄ – 1:50 (liquid effluent : good water)	7.96	8.03	7.99	71.35	72.80	72.07	220.76	225.37	223.06	302.94	310.96	306.95
D ₅ – Undiluted liquid effluent	5.36	5.54	6.69	40.39	41.04	40.71	119.46	124.10	121.78	151.55	154.31	152.93
D ₆ – Good water	7.81	7.86	7.83	70.84	71.70	71.27	218.51	222.57	220.54	300.55	305.39	302.97
S.Em±	0.10	0.16	0.09	1.24	2.74	1.50	3.39	3.52	2.46	4.44	5.46	3.50
CD at 5%	0.31	0.50	0.27	3.86	8.52	4.42	10.54	10.95	7.26	13.81	16.98	10.33

DAS – Days after sowing

Table 51. Dry matter accumulation in leaf (g/plant) at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	6.17	6.23	6.20	44.23	44.70	44.46	52.08	53.10	52.59	52.96	54.08	53.52
D ₂ – 1:10 (liquid effluent : good water)	5.95	6.15	6.05	43.20	43.85	43.45	49.48	50.50	49.99	50.43	51.40	50.91
D ₃ – 1:25 (liquid effluent : good water)	5.70	5.79	5.74	39.13	39.82	39.47	46.01	46.76	46.38	46.78	47.62	47.20
D ₄ – 1:50 (liquid effluent : good water)	5.53	5.56	5.54	37.15	37.80	37.47	44.60	45.20	44.90	45.35	46.15	45.75
D ₅ – Undiluted liquid effluent	3.58	3.71	3.65	20.87	21.02	20.95	24.12	24.58	24.35	24.64	25.18	24.91
D ₆ – Good water	5.40	5.42	5.40	36.88	37.20	37.04	44.28	44.71	44.50	45.32	45.28	45.80
S.E.m $\pm$	0.01	0.07	0.06	1.32	1.58	1.03	1.23	1.30	0.96	1.40	1.50	1.02
CD at 5%	0.03	0.27	0.18	4.10	4.91	3.04	3.82	4.40	2.83	4.35	4.66	3.01

DAS – Days after sowing

4.3.1.6.3 Dry matter accumulation in stem (g/plant) (Table 52)

Dry matter accumulation in stem varied significantly at all the growth stages of crop. Significantly the highest DMA in stem (2.80, 39.09, 84.06 and 77.86 at 30, 60, 90 DAS and at harvest, respectively) was recorded at lower dilution level of 1:5 however dilution levels of 1:5 and 1:10 were on par with each other. Significantly the lowest DMA in stem was noticed with irrigation by undiluted effluent (1.81, 19.77, 49.46 and 45.28 at 30, 60, 90 DAS and at harvest, respectively).

4.3.1.6.4 Dry matter accumulation in cob (g/plant) (Table 53)

At all growth stages, DMA in cob differed significantly for dilution levels. Irrigation by lower dilution levels of 1:5 and 1:10 recorded significantly higher DMA in cob of 112.35 and 109.29 at 90 DAS and 220.40 and 216.75 at harvest, respectively. Significantly the lowest DMA in cob of 44.96 at 90 DAS and 80.43 at harvest was recorded with irrigation by undiluted effluent.

4.3.1.6.5 Dry matter accumulation in tassel (g/plant) (Table 53)

Dry matter accumulation in tassel showed significant difference due to dilution levels. Both at 90 DAS and harvest, dilution levels of 1:5 recorded significantly higher DMA in tassel over rest of dilution levels (5.01 and 4.21 at 90 DAS and harvest, respectively), however it was on par with dilution levels of 1:10 and 1:25. Whereas, significantly the lowest DMA in tassel 2.77 and 2.31 at 90 DAS and harvest were recorded with irrigation by undiluted effluent.

4.3.1.7 Days to 50 per cent tasseling (Table 54)

Irrigation by dilution levels brought significant changes on days for 50 per cent tasseling. Lower dilution level of 1:5 took significantly lesser

Table 52. Dry matter accumulation in stem (g/plant) at different growth stages in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS			At harvest		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	2.76	2.95	2.80	38.96	39.22	39.09	83.28	84.84	84.06	77.13	78.60	77.86
D ₂ – 1:10 (liquid effluent : good water)	2.73	2.80	2.76	37.84	38.12	37.98	82.78	84.10	83.44	75.53	77.07	76.30
D ₃ – 1:25 (liquid effluent : good water)	2.56	2.59	2.57	35.98	36.44	36.21	78.47	80.00	79.23	71.91	73.06	72.49
D ₄ – 1:50 (liquid effluent : good water)	2.43	2.47	2.45	34.20	35.00	34.60	75.03	76.42	75.72	68.28	69.76	69.02
D ₅ – Undiluted liquid effluent	1.78	1.83	1.81	19.52	20.02	19.77	48.90	50.02	49.46	44.88	45.68	45.28
D ₆ – Good water	2.41	2.44	2.42	33.96	34.50	34.23	74.08	75.32	74.70	67.50	68.82	68.16
S.E.m±	0.09	0.08	0.06	1.66	2.00	1.30	2.58	3.06	2.03	1.84	2.05	1.37
CD at 5%	0.28	0.25	0.18	5.16	6.22	3.84	8.02	9.52	5.99	5.72	6.37	4.04

DAS – Days after sowing

Table 53. Dry matter accumulation in cob and tassel (g/plant) at 90 DAS and harvest in *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	90 DAS						At harvest			
	Cob			Tassel			Cob		Tassel	
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	1999-2000	2000-2001
D ₁ – 1:5 (liquid effluent : good water)	110.44	114.26	112.35	4.97	5.05	5.01	218.20	222.60	4.14	4.28
D ₂ – 1:10 (liquid effluent : good water)	107.66	110.92	109.29	4.87	5.08	4.97	214.23	219.27	4.13	4.22
D ₃ – 1:25 (liquid effluent : good water)	102.86	104.34	103.60	4.74	4.76	4.75	204.53	207.59	3.90	4.10
D ₄ – 1:50 (liquid effluent : good water)	96.70	99.23	97.94	4.43	4.52	4.47	185.63	190.21	3.68	3.78
D ₅ – Undiluted liquid effluent	43.70	46.70	44.96	2.72	2.80	2.77	79.75	81.11	2.28	2.34
D ₆ – Good water	95.75	98.06	96.90	4.40	4.48	4.44	184.03	187.55	3.70	3.74
S.Em±	3.39	4.45	2.71	0.16	0.26	0.15	2.40	2.78	0.14	0.18
CD at 5%	10.54	13.84	7.99	0.50	0.81	0.44	7.46	8.64	0.43	0.56

DAS – Days after sowing

days (64.15) to 50 per cent tasseling over rest of dilution levels but was found on par with dilution level of 1:10. Significantly higher number of days to 50 per cent tasseling was recorded with irrigation by undiluted effluent (66.50).

4.3.2 Yield and yield parameters

4.3.2.1 Cob length (cm) (Table 54)

There was significant difference in cob length due to dilution levels. Significantly lengthier cobs (19.79) were recorded at 1:5 dilution level over other dilution level and was found on par with dilution level of 1:10. Irrigation by undiluted effluent recorded significantly shortest cob length (11.82) over other dilution levels.

4.3.2.2 Cob girth (cm) (Table 54)

Irrigation by dilution levels brought significant influence on cob girth. Significantly higher cob girth of 5.23 was recorded at lower dilution of 1:5 over remaining dilution levels and significant lower cob girth of 3.06 was recorded with irrigation by undiluted effluent.

4.3.2.3 Weight per cob (g) (Table 54)

Weight per cob was differed significantly due to dilution levels. Significantly highest cob weight (210.40) was recorded at 1:5 dilution level and in next order was irrigation by dilution level of 1:10 (206.75). Whereas, irrigation by undiluted effluent recorded significantly lowest weight per cob (70.43) over remaining dilution levels.

4.3.2.4 Number of grains per cob (Table 55)

The dilution levels caused significant variation on number of grains per cob. Irrigation by 1:5 dilution level produced significantly higher

number of grains per cob (593.99) but was found on par with dilution level of 1:10. Irrigation by undiluted effluent recorded significantly the lowest number of grains per cob (295.74).

4.3.2.5 Grain weight per cob (g/cob) (Table 55)

There was significant influence of dilution levels on grain weight per cob. Significantly higher grain weight per cob was recorded at irrigation by dilution level of 1:5 (202.64) over rest of dilution levels but was found on par with other dilution level of 1:10. Significant the lowest grain weight per cob was recorded with irrigation by undiluted effluent (64.97).

4.3.2.6 Test weight (100-grain weight) (Table 55)

The test weight was influenced significantly by dilution levels. Lower dilution level of 1:5 and 1:10 recorded significantly higher test weight (32.43 and 32.03, respectively) than remaining dilution levels and both of these dilution levels found on par with each other. Whereas, irrigation by undiluted effluent recorded significantly the lowest test weight (18.58) over other dilution levels.

4.3.2.7 Grain yield (q/ha) (Table 56 and Fig.12)

The grain yield was significantly influenced by dilution levels. The lower dilution levels of 1:5 recorded significantly higher grain yield (76.82) and was noticed to be on par with dilution level of 1:10 but both were significantly superior over other dilution levels. Whereas, significantly the lowest grain yield (24.06) was recorded with irrigation by undiluted effluent.

Table 55. Number of grains per cob, grain weight per cob (g) and test weight (100-grain weight) of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	Number of grains per cob			Grain weight per cob			100 grain weight		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	588.42	599.56	593.99	199.00	206.29	202.64	32.12	32.74	32.43
D ₂ – 1:10 (liquid effluent : good water)	574.72	585.21	579.96	192.13	199.43	195.78	31.69	32.37	32.03
D ₃ – 1:25 ((liquid effluent : good water)	541.35	560.59	555.07	175.25	181.93	178.59	30.07	30.67	30.37
D ₄ – 1:50 (liquid effluent : good water)	518.90	527.68	523.29	159.60	164.45	162.02	28.83	29.27	29.05
D ₅ –Undiluted liquid effluent	292.94	298.54	295.74	64.05	65.89	64.97	18.45	18.72	18.58
D ₆ – Good water	514.11	522.66	518.38	155.90	161.05	158.47	28.38	28.90	28.64
S.Em±	8.15	8.79	6.00	4.41	4.65	3.20	0.36	0.55	0.31
CD at 5%	25.34	27.34	17.67	13.71	14.46	9.45	1.12	1.71	0.91

4.3.2.8 Stover yield (q/ha) (Table 56 and Fig.12)

Variation in dilution levels recorded significant differences on stover yield. The stover yield at irrigation by undiluted effluent was 36.87 which increased significantly with decrease in dilution levels. Hence, lower dilution level of 1:5 was significantly superior (106.77) over all dilution levels but was found on par with 1:10 dilution level.

4.3.2.9 Harvest index (Table 56)

Harvest index (HI) also varied significantly by variation in dilution levels. Significantly higher harvest index (0.418) was recorded at 1:5 dilution level and was found on par with all dilution levels except irrigation by undiluted effluent.

4.3.3 Quality parameters

4.3.3.1 Protein (%) (Table 57)

The dilution levels brought significant influence on protein content in grains. Higher protein content (11.66) was recorded at irrigation by undiluted effluent and was found on par with lower dilution level of 1:5. Irrigation by ground water recorded significantly lower protein content in grains (10.90) over all dilution levels.

4.3.3.2 Reducing sugar content (%) (Table 57)

Reducing sugar content in grain was influenced significantly by dilution levels. Significantly the highest reducing content in grain (1.35) was recorded at irrigation by undiluted effluent and was found on par with lower dilution level of 1:5. Whereas, irrigation by good water registered significantly lower reducing sugar content in grains (1.17).

Table 56. Grain yield (q/ha), stover yield (q/ha) and harvest index (HI) of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	Grain yield			Stover yield			Harvest index		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	75.05	78.61	76.82	104.85	108.70	106.77	0.417	0.419	0.418
D ₂ – 1:10 (liquid effluent : good water)	74.26	75.82	75.01	103.67	105.84	104.75	0.417	0.417	0.417
D ₃ – 1:25 (liquid effluent : good water)	70.35	72.37	71.36	99.20	101.20	100.20	0.415	0.417	0.416
D ₄ – 1:50 (liquid effluent : good water)	67.18	68.24	67.71	95.26	94.40	95.83	0.413	0.414	0.413
D ₅ – Undiluted liquid effluent	23.86	24.26	24.06	36.70	37.05	36.87	0.394	0.396	0.395
D ₆ – Good water	66.58	67.36	66.97	93.60	94.75	94.17	0.415	0.415	0.415
S.E.m±	1.09	1.21	0.82	1.50	1.57	1.09	0.006	0.008	0.005
CD at 5%	3.39	3.76	2.42	4.66	4.88	3.21	0.018	0.025	0.015

LEGEND

Dilution levels

D₁ - 1:5 (liquid effluent : good water)

D₂ - 1:10 (liquid effluent:good water)

D₃ - 1:25 (liquid effluent: good water)

D₄ - 1:50 (liquid effluent:good water)

D₅ - Undiluted liquid effluent

D₆ - Good water.

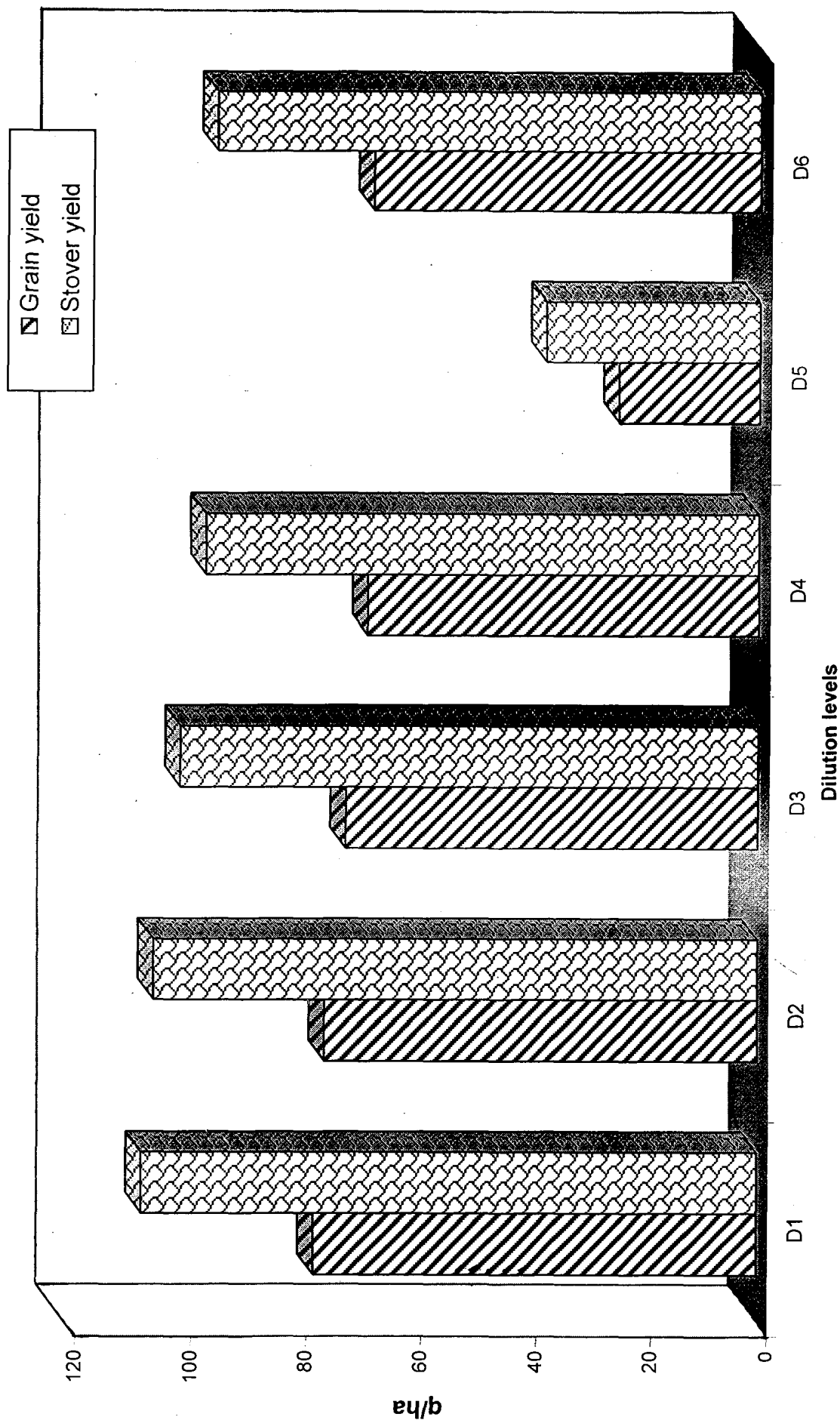


Fig. 12. Grain yield (q/ha) and straw yield (q/ha) of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Table 57. Protein, reducing sugar and starch contents (%) of *rabi* maize grain as influenced by dilution of liquid distillery effluent with good water

Dilution level	Protein			Reducing sugar content			Starch		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	11.54	11.78	11.66	1.32	1.35	1.33	67.02	67.00	67.01
D ₂ – 1:10 (liquid effluent : good water)	11.39	11.41	11.40	1.29	1.31	1.30	67.10	67.12	67.11
D ₃ – 1:25 (liquid effluent : good water)	11.04	11.15	11.10	1.22	1.26	1.24	67.25	67.30	67.27
D ₄ – 1:50 (liquid effluent : good water)	10.90	11.11	11.01	1.17	1.19	1.18	66.80	66.82	66.81
D ₅ – Undiluted liquid effluent	11.67	11.71	11.69	1.33	1.37	1.35	67.28	67.32	67.30
D ₆ – Good water	10.80	11.01	11.90	1.16	1.18	1.17	67.30	67.34	67.32
S.E.m±	0.04	0.03	0.03	0.01	0.02	0.01	0.32	0.35	0.24
CD at 5%	0.12	0.09	0.09	0.03	0.06	0.03	NS	NS	NS

NS – Non significant

4.3.3.3 Starch content (%) (Table 57)

The starch content in grains was not influenced significantly by dilution levels.

4.3.4 Nutrient contents in plant

4.3.4.1 Nutrient contents in plant anthesis

4.3.4.1.1 Nitrogen (%) (Table 58)

Nitrogen content was differed significantly due to dilution levels. Significantly higher nitrogen content was recorded at irrigation by undiluted effluent (3.22) over rest of dilution levels but was found on par with lower dilution level of 1:5 and 1:10. Whereas, irrigation by good water recorded significantly lower nitrogen content in plant (3.06) and was found on par with higher dilution level of 1:50.

4.3.4.1.2 Phosphorus (%) (Table 58)

Phosphorus content in plant varied significantly due to dilution levels. Significantly higher phosphorus content in plant (0.427) was recorded at irrigation by undiluted effluent. Significantly the lowest phosphorus content was recorded with irrigation by good water over rest of dilution levels.

4.3.4.1.3 Potassium (%) (Table 58)

The dilution levels brought significant influence on potassium content in plant. Significantly highest potassium content was recorded at irrigation by undiluted effluent (2.04) and was found on par with lower dilution level of 1:5. Whereas irrigation by good water recorded significantly lower potassium content (1.86) and was found on par with irrigation by higher dilution level of 1:50.

Table 58. Nitrogen, phosphorus and potassium contents (%) of *rabi* maize at anthesis as influenced by of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	Nitrogen			Phosphorus			Potassium		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	3.20	3.23	3.22	0.382	0.403	0.392	1.99	2.02	2.01
D ₂ – 1:10 (liquid effluent : good water)	3.16	3.17	3.17	0.373	0.386	0.379	1.95	1.98	1.97
D ₃ – 1:25 (liquid effluent : good water)	3.11	3.13	3.12	0.365	0.383	0.374	1.90	1.92	1.91
D ₄ – 1:50 (liquid effluent : good water)	3.08	3.08	3.08	0.344	0.362	0.353	1.88	1.89	1.86
D ₅ – Undiluted liquid effluent	3.22	3.23	3.23	0.411	0.432	0.427	2.03	2.04	2.04
D ₆ – Good water	3.05	3.06	3.06	0.335	0.325	0.330	1.86	1.85	1.86
S.Em±	0.03	0.04	0.02	0.004	0.005	0.003	0.02	0.03	0.02
CD at 5%	0.09	0.12	0.07	0.012	0.016	0.009	0.06	0.09	0.06

4.3.4.2 Nutrient contents in plant at harvest and their total uptake

4.3.4.2.1 Nitrogen contents (%) in grain and stover and total nitrogen uptake (kg/ha) (Table 59 and Fig.13)

Nitrogen contents in grain and stover differed significantly due to dilution levels. Significantly higher nitrogen content in grain and stover was recorded with irrigation by undiluted effluent (1.87 and 0.501, respectively) over other dilution levels but was found on par with 1:5 and 1:10 dilution levels. Significantly lower nitrogen contents in grain (1.74) and stover (0.430) were recorded with irrigation by good water and this was found on par with lower dilution level of 1:5.

Total uptake of nitrogen by crop was significantly influenced by dilution levels. A significantly higher total nitrogen uptake was recorded at dilution level of 1:5 (195.45) over other dilution levels but was found on par with next dilution level of 1:10. Significantly the lowest total nitrogen uptake of (63.47) was recorded with irrigation by undiluted effluent.

4.3.4.2.2 Phosphorus contents (%) in grain and stover and total phosphorus uptake (kg/ha) (Table 60 and Fig.13)

The dilution levels did not bring significant difference either in grain or in stover. But, the higher values were seen at lower dilution levels which received higher concentration of effluent in the form of irrigation.

Total phosphorus uptake was varied significantly and irrigation by 1:5 dilution level recorded significantly higher total phosphorus uptake (43.26) as compared to other dilution levels but was found on par with dilution level of 1:10. Whereas, significantly the lowest total phosphorus uptake was recorded with irrigation by undiluted effluent (14.49).

Table 59. Nitrogen contents (%) in grain and stover and total nitrogen uptake (kg/ha) by *rabi* maize at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Nitrogen content						Total uptake		
	Grain			Stover					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ ~ 1:5 (liquid effluent : good water)	1.84	1.88	1.86	0.489	0.495	0.492	191.69	199.22	195.45
D ₂ ~ 1:10 (liquid effluent : good water)	1.82	1.83	1.82	0.476	0.484	0.480	184.50	189.98	187.24
D ₃ ~ 1:25 ((liquid effluent : good water)	1.77	1.78	1.77	0.458	0.466	0.462	170.13	175.80	172.96
D ₄ ~ 1:50 (liquid effluent : good water)	1.74	1.78	1.76	0.430	0.436	0.433	157.85	163.50	160.67
D ₅ ~Undiluted liquid effluent	1.87	1.87	1.87	0.499	0.503	0.501	62.93	64.01	63.47
D ₆ ~ Good water	1.73	1.76	1.74	0.424	0.436	0.430	154.87	159.86	157.36
S.Em±	0.02	0.03	0.02	0.007	0.006	0.005	4.13	4.41	3.02
CD at 5%	0.06	0.09	0.06	0.021	0.018	0.015	12.81	13.71	8.90

Table 60. Phosphorus contents (%) in grain and stover and total phosphorus uptake (kg/ha) by *rabi* maize at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Phosphorus content						Total uptake		
	Grain			Stover					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	0.290	0.294	0.292	0.193	0.197	0.195	42.48	44.04	43.26
D ₂ – 1:10 (liquid effluent : good water)	0.285	0.290	0.288	0.194	0.196	0.195	41.35	42.73	42.04
D ₃ – 1:25 (liquid effluent : good water)	0.280	0.286	0.283	0.191	0.195	0.193	38.68	40.40	39.54
D ₄ – 1:50 (liquid effluent : good water)	0.277	0.281	0.279	0.186	0.190	0.188	36.33	37.49	36.91
D ₅ – Undiluted liquid effluent	0.295	0.301	0.298	0.196	0.201	0.198	14.23	14.75	14.49
D ₆ – Good water	0.277	0.279	0.278	0.184	0.186	0.185	35.66	36.41	36.03
S.Em±	0.009	0.01	0.007	0.009	0.008	0.006	1.18	1.47	0.94
CD at 5%	NS	NS	NS	NS	NS	NS	3.67	4.57	2.77

NS – Non significant

4.3.4.2.3 Potassium contents (%) in grain and stover and total potassium uptake (kg/ha) (Table 61 and Fig.13)

Potassium contents in grain and stover were influenced significantly by dilution levels. Irrigation by undiluted effluent and lower dilution levels of 1:5 and 1:10 recorded higher potassium contents in grain and stover and all these found on par among themselves. Whereas, irrigation by good water recorded significantly lower potassium contents in grain and stover however, these were found on par with higher dilution level of 1:50.

The total potassium uptake was significantly higher at 1:5 dilution level (173.79) as compared to other dilution levels and was found on par with other dilution level of 1:10. Whereas, significantly the lowest total potassium uptake (56.10) was recorded with irrigation by undiluted effluent.

4.3.4.2.4 Zinc contents (ppm) in grain and stover and total zinc uptake (kg/ha) (Table 62)

Zinc contents in grain showed significant variation due to dilution levels. Highest value of zinc was recorded with irrigation by undiluted effluent (22.60) which was found on par with 1:5 dilution level. Whereas zinc content in stover was not varied significantly due to dilution levels.

Irrigation by lower dilution level of 1:5 recorded significantly higher total zinc uptake (0.485) over rest but was found on par with irrigation by 1:10. Whereas, significantly the lowest zinc uptake was recorded with irrigation by undiluted effluent (0.163) followed by irrigation with good water (0.391).

Table 61. Potassium contents (%) in grain and stover and total potassium uptake (kg/plant) by *rabi* maize at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Potassium content						Total uptake		
	Grain			Stover					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
	D ₁ – 1:5 (liquid effluent : good water)	0.368	0.376	0.372	1.34	1.38	1.36	169.79	177.80
D ₂ – 1:10 (liquid effluent : good water)	0.364	0.372	0.368	1.33	1.36	1.34	164.91	172.14	168.52
D ₃ – 1:25 (liquid effluent : good water)	0.334	0.340	0.337	1.27	1.29	1.28	149.51	155.12	152.31
D ₄ – 1:50 (liquid effluent : good water)	0.329	0.333	0.331	1.21	1.24	1.22	137.36	142.26	139.81
D ₅ –Undiluted liquid effluent	0.373	0.377	0.375	1.36	1.40	1.38	52.26	59.95	56.10
D ₆ – Good water	0.329	0.331	0.330	1.20	1.21	1.20	134.22	136.94	135.58
S.E.m±	0.008	0.099	0.006	0.03	0.03	0.02	2.39	2.97	1.90
CD at 5%	0.025	0.308	0.019	0.09	0.09	0.06	7.43	9.24	5.60

LEGEND

Dilution levels

D₁ - 1:5 (liquid effluent : good water)

D₂ - 1:10 (liquid effluent:good water)

D₃ - 1:25 (liquid effluent: good water)

D₄ - 1:50 (liquid effluent:good water)

D₅ - Undiluted liquid effluent

D₆ - Good water.

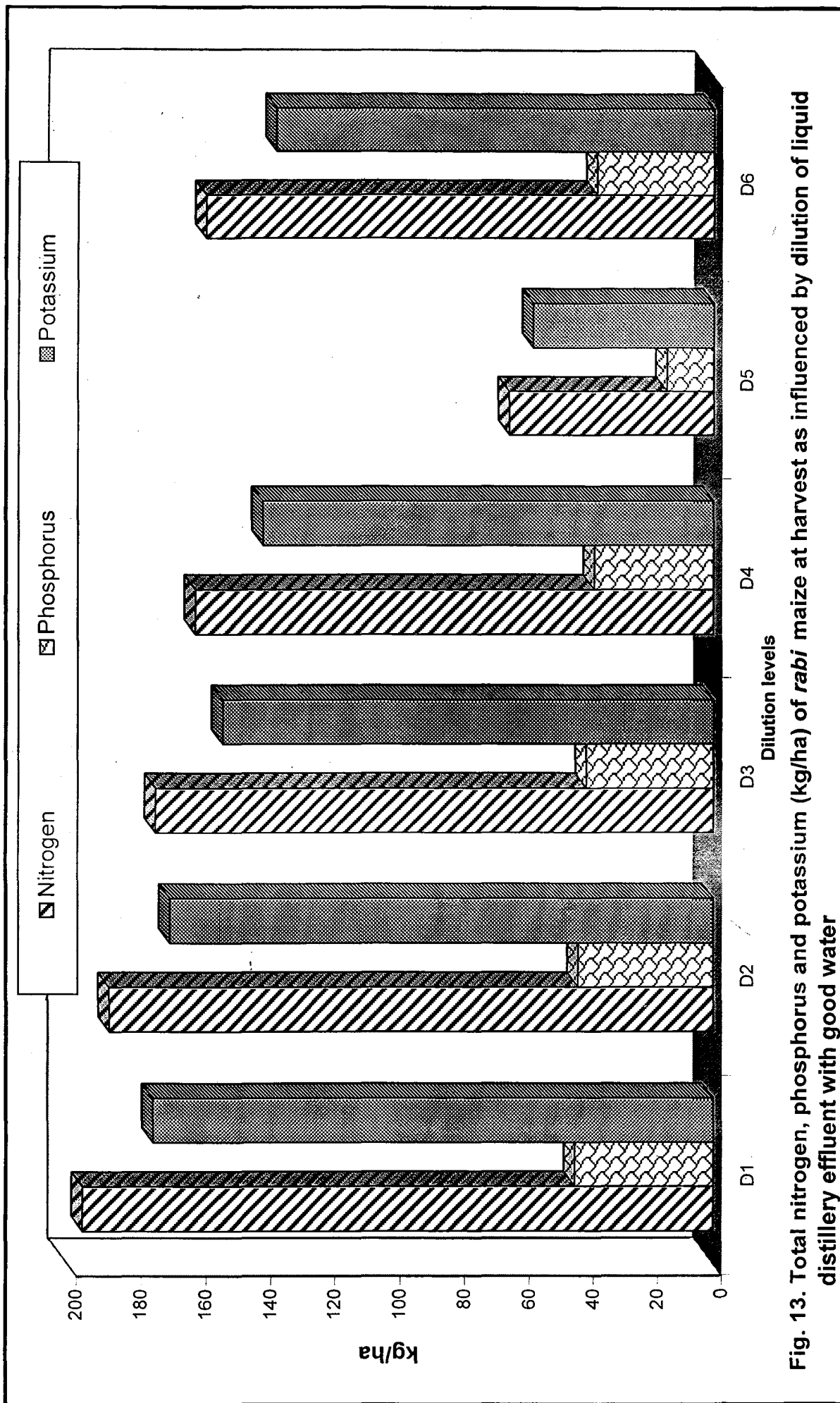


Fig. 13. Total nitrogen, phosphorus and potassium (kg/ha) of *rabi* maize at harvest as influenced by dilution of liquid distillery effluent with good water

4.3.4.2.5 Copper contents (ppm) in grain and stover and total copper uptake (kg/ha) (Table 62)

Neither in grain nor in stover, dilution levels brought significant difference on copper content however higher values were seen at lower dilution levels.

The total copper uptake was influenced significantly by variation in dilution levels. Irrigation by lower dilution level of 1:5 recorded higher total uptake of 0.172 which was found on par with 1:10 dilution level. Whereas, significantly lower total copper uptake was recorded at irrigation by undiluted effluent (0.057).

4.3.4.2.6 Iron contents (ppm) in grain and stover and total iron uptake (kg/ha) (Table 63)

The dilution levels did not influence significantly the iron contents in grain and stover. However, higher values were found at lower dilution levels.

Irrigation by 1:5 dilution level recorded significantly higher total iron uptake (3.12) as compared to irrigation by other dilution levels. Whereas, significantly the lowest total iron uptake (1.04) was recorded with irrigation by undiluted effluent.

4.3.4.2.7 Manganese contents (ppm) in grain and stover and total manganese uptake (kg/ha) (Table 63)

The dilution levels failed to bring significant influence over manganese contents in grain and stover. Though the values were nonsignificant, higher values were seen at lower dilution levels.

Table 62. Zinc and copper contents (ppm) in grain and stover and total zinc and copper uptake (kg/ha) by *rabi* maize at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Zinc						Copper											
	Zinc content						Copper content											
	Total uptake						Total uptake											
	Grain			Stover			Grain			Stover								
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled						
D ₁ – 1:5 (liquid effluent : good water)	22.30	22.60	22.45	29.06	29.64	29.35	0.476	0.494	0.485	7.72	7.10	7.81	10.41	10.63	10.52	0.169	0.175	0.172
D ₂ – 1:10 (liquid effluent : good water)	21.44	21.68	21.56	28.90	29.30	29.10	0.458	0.474	0.466	7.71	7.87	7.79	10.36	10.56	10.46	0.164	0.171	0.167
D ₃ – 1:25 (liquid effluent : good water)	21.10	21.34	21.22	28.33	28.71	28.52	0.430	0.444	0.437	7.63	7.79	7.71	10.25	10.46	10.35	0.156	0.162	0.159
D ₄ – 1:50 (liquid effluent : good water)	20.06	20.14	20.10	27.88	28.26	28.07	0.400	0.409	0.404	7.59	7.75	7.67	10.24	10.40	10.32	0.148	0.153	0.150
D ₅ –Undiluted liquid effluent	22.47	22.73	22.60	29.37	29.73	29.55	0.162	0.165	0.163	7.75	7.91	7.83	10.49	10.71	10.60	0.056	0.059	0.057
D ₆ – Good water	20.06	20.10	20.08	27.20	27.36	27.28	0.388	0.394	0.391	7.60	7.68	7.64	10.25	10.33	10.29	0.146	0.150	0.148
S.E.m±	0.84	0.82	0.59	1.55	1.55	1.10	0.015	0.010	0.01	0.38	0.42	0.28	6.47	0.48	0.34	0.005	0.006	0.004
CD at 5%	NS	2.55	1.74	NS	NS	NS	0.046	0.031	0.03	NS	NS	NS	NS	NS	NS	0.015	0.018	0.012

NS - Non significant

Table 63. Iron and manganese contents (ppm) in grain and stover and total iron and manganese uptake (kg/ha) by *rabi* maize at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Iron						Manganese					
	Iron content			Total uptake			Manganese content			Total uptake		
	Grain			Stover			Grain			Stover		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	156.47	159.63	158.05	177.08	180.66	178.87	3.06	3.18	3.12	21.87	22.31	22.09
D ₂ – 1:10 (liquid effluent : good water)	156.26	159.2	157.84	176.14	179.70	177.92	2.99	3.11	3.05	21.60	22.04	21.82
D ₃ – 1:25 (liquid effluent : good water)	156.55	159.69	157.12	174.94	178.48	176.71	2.84	2.96	2.90	21.42	21.86	21.64
D ₄ – 1:50 (liquid effluent : good water)	156.40	157.54	156.97	174.62	176.12	175.37	2.71	2.78	2.74	21.09	21.51	21.30
D ₅ – Undiluted liquid effluent	158.82	162.04	160.43	177.12	180.70	178.91	1.03	1.06	1.04	22.79	23.75	23.02
D ₆ – Good water	155.93	157.07	156.50	174.98	175.28	175.13	2.68	2.72	2.70	21.00	21.05	21.02
S.E.m±	2.93	3.25	2.19	3.85	3.67	2.66	0.04	0.04	0.02	0.78	0.79	0.55
CD at 5%	NS	NS	NS	NS	NS	NS	0.12	0.12	0.09	NS	NS	NS

NS – Non significant

The highest total manganese uptake (1.39) was recorded at dilution level of 1:5 which was found significantly superior to remaining dilution levels except 1:10 dilution level. Further, significantly the lowest total manganese uptake (0.48) was recorded with irrigation by undiluted effluent.

4.3.5 Physico-chemical properties of soil

4.3.5.1 Physical properties

4.3.5.1.1 Bulk density (Mg/m^3) (Table 64)

Irrigation by dilution levels exhibited significant variation on bulk density of soil. The highest bulk density (1.51) was recorded with irrigation by good water. Whereas, irrigation by undiluted effluent have reduced the bulk density significantly (1.39) but was found on par with irrigation by dilution levels of 1:5, 1:10 and 1:25.

4.3.5.2 Chemical properties

4.3.5.2.1 Soil reaction (pH) (Table 64)

The dilution levels were significantly differed for soil reaction. Irrigation by undiluted effluent recorded significantly higher soil pH (7.87) but was found on par with dilution level of 1:5. Significantly lower soil pH (6.93) was found with irrigation by good water.

4.3.5.2.2 Electrical conductivity (dSm^{-1}) (Table 64)

The electrical conductivity (EC) of soil showed significant variation due to irrigation by dilution levels. The EC of soil increased significantly with decrease in dilution levels and significantly highest EC of soil was recorded with irrigation by undiluted effluent (1.04). Whereas, significantly the lowest EC of soil (0.48) was recorded with irrigation by good water.

Table 64. Bulk density (Mg/m^3), soil reaction (pH), electrical conductivity (EC, dSm^{-1}) and organic carbon (OC, %) in soil after harvest of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	Bulk density			pH			EC			OC		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	1.43	1.41	1.42	7.75	7.89	7.82	0.79	0.83	0.81	0.49	0.51	0.50
D ₂ – 1:10 (liquid effluent : good water)	1.48	1.43	1.45	7.63	7.67	7.65	0.67	0.71	0.69	0.47	0.48	0.48
D ₃ – 1:25 (liquid effluent : good water)	1.50	1.44	1.47	7.51	7.57	7.54	0.52	0.56	0.54	0.46	0.48	0.47
D ₄ – 1:50 (liquid effluent : good water)	1.52	1.50	1.51	7.10	7.12	7.11	0.49	0.52	0.50	0.46	0.47	0.47
D ₅ – Undiluted liquid effluent	1.40	1.38	1.39	7.80	7.94	7.87	1.01	1.07	1.04	0.50	0.54	0.52
D ₆ – Good water	1.52	1.50	1.51	6.94	6.93	6.93	0.48	0.49	0.48	0.47	0.46	0.46
S.E.m $\pm$	0.06	0.05	0.04	0.08	0.09	0.06	0.03	0.04	0.03	0.007	0.008	0.006
CD at 5%	0.19	0.16	0.11	0.26	0.28	0.18	0.09	0.12	0.09	0.022	0.025	0.018

4.3.5.2.3 Organic carbon (%) (Table 64)

Organic carbon content of soil was differed significantly with respect to dilution levels. Significantly higher organic carbon (0.52) was recorded with irrigation by undiluted effluent. Irrigation by good water registered significantly lower organic carbon content (0.46) as compared to higher dilution levels of 1:50 and 1:25.

4.3.5.2.4 Nutrient contents in soil

4.3.5.2.4.1 Available nitrogen (kg/ha) (Table 65 and Fig.14)

Variation in dilution levels caused significant variation on available nitrogen content of soil. Significantly higher available nitrogen (402.84) was recorded with irrigation by undiluted effluent over rest of dilution levels. Whereas, significantly lowest available nitrogen content in soil (223.50) was recorded with irrigation by good water.

4.3.5.2.4.2 Available phosphorus (kg/ha) (Table 65 and Fig.14)

Available phosphorus content of soil differed significantly due to different dilution levels. Irrigation by undiluted effluent (51.80) found significantly higher available phosphorus over other dilution levels. Irrigation by good water recorded significantly lower available phosphorus content (30.67) than remaining dilution levels but was found on par with dilution levels of 1:50 and 1:25.

4.3.5.2.4.3 Available potassium (kg/ha) (Table 65 and Fig.14)

The dilution levels caused significant variation on available potassium content. Significantly higher available potassium content was recorded with irrigation by undiluted effluent (640.60). Whereas, irrigation by good water recorded significantly lower potassium content (367.80) as compared to all dilution levels.

Table 65. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	Available N			Available P ₂ O ₅			Available K ₂ O		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ - 1:5 (liquid effluent : good water)	348.73	355.57	351.95	35.66	38.34	37.00	505.50	512.30	508.90
D ₂ - 1:10 (liquid effluent : good water)	291.84	296.92	294.38	35.40	36.08	35.74	460.60	473.50	467.05
D ₃ - 1:25 (liquid effluent : good water)	260.10	265.04	262.57	33.56	34.22	33.89	435.10	443.50	439.30
D ₄ - 1:50 (liquid effluent : good water)	244.06	246.66	245.36	31.22	31.85	31.53	395.50	407.50	401.50
D ₅ - Undiluted liquid effluent	399.01	406.67	402.84	49.90	51.80	50.85	635.49	645.71	640.60
D ₆ - Good water	225.05	221.95	223.50	31.10	30.25	30.67	370.10	365.10	367.80
S.Em±	7.14	7.71	5.25	2.03	2.24	1.51	8.92	9.88	6.65
CD at 5%	22.21	23.98	15.49	6.31	6.97	4.45	27.74	30.73	19.62

LEGEND

Dilution levels

D₁ - 1:5 (liquid effluent : good water)

D₂ - 1:10 (liquid effluent:good water)

D₃ - 1:25 (liquid effluent: good water)

D₄ - 1:50 (liquid effluent:good water)

D₅ - Undiluted liquid effluent

D₆ - Good water.

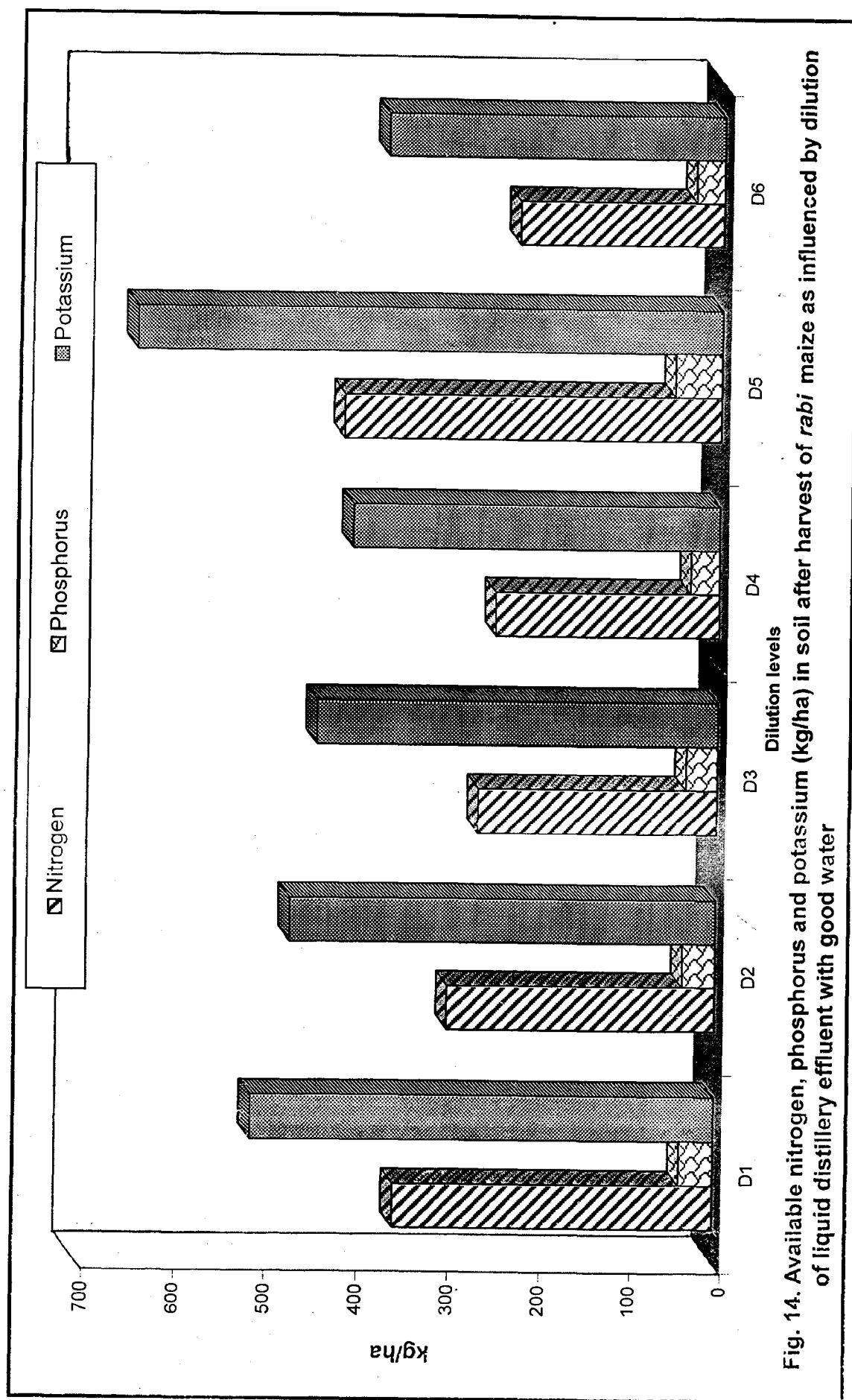


Fig. 14. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

4.3.5.2.4.4 DTPA extractable (available) micronutrients in soil (ppm)**(Table 66)****4.3.5.2.4.4.1 Zinc**

The variation in dilution levels caused significant variation on zinc content of soil. A significantly higher zinc in soil was recorded with irrigation by undiluted effluent (3.75), this was gradually decreased with increase in dilution levels. Whereas, significantly the lowest zinc content recorded with irrigation by good water (2.06).

4.3.5.2.4.4.2 Copper

Copper content in soil was differed significantly due to dilution levels. Irrigation by undiluted effluent recorded significantly higher copper content (2.23). Whereas, irrigation by good water recorded significantly the lowest copper content in soil (1.78) however it was found on par with higher dilution level of 1:50.

4.3.5.2.4.4.3 Iron

Iron content in soil showed significant variation with dilution levels. Undiluted effluent treated plot recorded highest iron content (11.17) which was found significantly superior to all dilution levels. Whereas, significantly the lowest iron content in soil was recorded with irrigation by good water (4.80).

4.3.5.2.4.4.4 Manganese

The dilution levels offered significantly with respect to manganese content in soil. The maximum content of manganese (9.02) was found with irrigation by undiluted effluent which was found significantly higher over all dilution levels. Whereas, irrigation by good water recorded

Table 66. DTPA extractable zinc, copper, iron and manganese contents (ppm) in soil after harvest of *rabi* maize as influenced by dilution of liquid distillery effluent with good water

Dilution level	Zinc			Copper			Iron			Manganese		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	3.40	3.56	3.48	2.09	2.13	2.11	8.92	9.78	9.35	8.93	9.11	9.02
D ₂ – 1:10 (liquid effluent : good water)	3.20	3.31	3.25	2.02	2.10	2.06	7.04	7.40	7.22	8.86	9.04	8.95
D ₃ – 1:25 (liquid effluent : good water)	3.08	3.18	3.13	1.89	1.93	1.91	5.08	5.22	5.15	8.79	8.97	8.88
D ₄ – 1:50 (liquid effluent : good water)	2.90	2.96	2.93	1.80	1.84	1.82	4.91	5.01	4.96	8.83	8.87	8.85
D ₅ – Undiluted liquid effluent	3.51	3.99	3.75	2.19	2.26	2.23	10.59	11.75	11.17	9.12	9.28	9.20
D ₆ – Good water	2.08	2.04	2.06	1.78	1.77	1.78	4.82	4.78	4.80	8.80	8.76	8.78
S.E.m $\pm$	0.07	0.07	0.05	0.06	0.04	0.03	0.11	0.14	0.09	0.06	0.08	0.05
CD at 5%	0.22	0.22	0.15	0.18	0.12	0.10	0.34	0.43	0.27	0.18	0.25	0.15

significantly lower manganese content in soil (8.78) as compared to other dilution levels except 1:50 and 1:25.

4.3.6 Economics (Rs./ha) (Table 67)

Highest gross income (36,976) was recorded with lower dilution level of 1:5. This was found on par with next dilution level of 1:10. Whereas, the lowest gross income was recorded with irrigation by undiluted effluent (11,656). The highest net return of 25,212 was obtained when 1:5 dilution level was used which again closely followed by 1:10 dilution level. Whereas, irrigation by undiluted effluent recorded the lowest net return (1,637). The benefit:cost ratio also followed the same trend.

4.4 Experiment 4 : Studies on the performance of wheat against graded dilution of liquid distillery effluent as a source of irrigation

4.4.1 Growth parameters

4.4.1.1 Plant height (cm) (Table 68)

Plant height showed significant variation due to different levels of liquid distillery effluent with good water. The lower dilution level of 1:5 recorded significantly taller plants at all the growth stages (7.62, 67.39 and 96.25 at 30, 60 and 90 DAS, respectively) as compared to other dilution levels. Whereas, significantly shortest plants were observed with irrigation by undiluted effluent irrespective of all the growth stages (5.38, 40.16 and 55.32 at 30, 60, 90 DAS, respectively).

4.4.1.2 Leaf area index (Table 69)

At all growth stages, leaf area index (LAI) was differed significantly due to dilution levels. Higher LAI was recorded at 1:50 dilution level at all

Table 67. Economics as influenced by dilution of liquid distillery effluent with good water in *rabi* maize

Nitrogen substitution level	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)			Net returns (Rs./ ha)			B:C ratio		
		1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ - 1:5 (liquid effluent : good water)	11764	36131	37820	36976	24367	26056	25212	2.07	2.21	2.14
D ₂ - 1:10 (liquid effluent : good water)	11576	35750	36500	36111	24174	24924	24535	2.08	2.15	2.11
D ₃ - 1:25 (liquid effluent : good water)	11354	33890	34820	34366	22536	23466	23012	1.98	2.07	2.02
D ₄ - 1:50 (liquid effluent : good water)	11146	32374	32864	32626	21228	21718	21480	1.90	1.95	1.92
D ₅ -Undiluted liquid effluent	10019	11563	11747	11656	1544	1728	1637	0.15	0.17	0.16
D ₆ - Good water	10911	32067	32444	32255	21156	21533	21344	1.94	1.97	1.95
S.Em±		940	985	681	811	843	585	0.02	0.02	0.01
CD at 5%		2923	3063	2009	2522	2622	1726	0.06	0.06	0.03

Table 68. Plant height (cm) of wheat at different growth stages as influenced by dilution of liquid distillery effluent with good water

Dilution level	30 DAS			60 DAS			90 DAS		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	7.55	7.69	7.62	66.04	68.74	67.39	94.34	98.16	96.25
D ₂ – 1:10 (liquid effluent : good water)	7.32	7.44	7.38	63.30	65.86	64.58	91.60	95.34	93.47
D ₃ – 1:25 (liquid effluent : good water)	7.06	7.18	7.12	60.66	61.84	61.25	87.23	88.98	88.10
D ₄ – 1:50 (liquid effluent : good water)	6.70	6.82	6.76	56.74	57.86	57.30	82.38	84.04	83.21
D ₅ – Undiluted liquid effluent	5.34	5.43	5.38	39.76	40.56	40.16	54.76	55.88	55.32
D ₆ – Good water	6.62	6.68	6.65	55.89	56.43	56.16	80.75	82.41	81.58
S.E.m±	0.20	0.22	0.15	0.42	0.61	0.37	0.86	0.76	0.58
CD at 5%	0.62	0.68	0.44	1.31	1.90	1.09	2.67	2.36	1.69

DAS – Days after sowing

growth stages (1.91, 3.48 and 2.23 at 30, 60, 90 DAS, respectively). However, 1:50 dilution level was found on par with irrigation by good water. Whereas, irrigation by good water recorded significantly lowest leaf area index at all growth stages (1.53, 1.82 and 0.64 at 30, 60, 90 DAS, respectively).

4.4.1.3 Leaf area duration (days) (Table 69)

Leaf area duration (LAD) differed significantly due to dilution levels at both 30-60 DAS and 60-90 DAS. Highest LAD of 80.85 at 30-60 DAS and 85.65 at 60-90 DAS was recorded at higher dilution level of 1:50 which were found significantly superior over all the dilution levels except irrigation by good water. Significantly the lowest LAD was recorded with irrigation by undiluted effluent at both 30-60 DAS (50.32) and 60-90 DAS (37.05).

4.4.1.4 Number of productive tillers per metre row length (Table 70)

The productive tillers differed significantly due to different dilution levels. Significantly the highest number of productive tillers was observed in 1:50 dilution level (118.40). However, it found on par with irrigation by good water. Significantly the lowest number of productive tillers were recorded at irrigation by undiluted effluent (35.59) followed by lower dilution level of 1:5.

4.4.1.5 Dry matter production at its accumulation

4.4.1.5.1 Total dry matter production (g/m row length (Table 70)

There was significant variation on total dry matter (TDM) production due to variation in dilution levels. Dilution level of 1:50 recorded the highest TDM production at all the growth stages of crop (54.03, 122.11 and 213.11 at 30, 60, 90 DAS, respectively) and was

Table 69. Leaf area index (LAI) and leaf area duration (LAD, days) of wheat at different growth stages as influenced by dilution of liquid distillery effluent with good water

Dilution level	Leaf area index (LAI)										Leaf area duration (LAD)			
	30 DAS			60 DAS			90 DAS			30-60 DAS			60-90 DAS	
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001
														Pooled
D ₁ – 1:5 (liquid effluent : good water)	1.73	1.80	1.76	2.64	2.72	2.68	1.66	1.70	1.68	65.55	67.80	66.67	64.50	66.30
D ₂ – 1:10 (liquid effluent : good water)	1.78	1.86	1.82	2.81	2.93	2.87	1.75	1.83	1.79	68.85	71.85	70.35	68.40	71.40
D ₃ – 1:25 (liquid effluent : good water)	1.82	1.87	1.84	3.02	3.06	3.04	1.87	1.93	1.90	72.60	73.95	73.27	73.35	74.85
D ₄ – 1:50 (liquid effluent : good water)	1.89	1.93	1.91	3.45	3.51	3.48	2.20	2.26	2.23	80.10	81.60	80.85	84.75	86.55
D ₅ – Undiluted liquid effluent	1.51	1.55	1.53	1.80	1.85	1.82	0.63	0.66	0.64	49.65	51.00	50.32	36.45	37.05
D ₆ – Good water	1.87	1.91	1.89	3.28	3.32	3.30	1.99	2.05	2.02	76.95	78.15	77.55	78.75	80.25
S.E.m±	0.05	0.06	0.04	0.07	0.08	0.04	0.04	0.16	0.07	2.98	3.19	2.18	3.02	3.20
CD at 5%	0.15	0.18	0.12	0.22	0.25	0.12	0.12	0.49	0.21	9.27	9.92	6.43	9.39	9.95
DAS – Days after sowing														

Table 70. Number of productive tillers per metre row length and total dry matter production (g/m row length) of wheat at different growth stages as influenced by dilution of liquid distillery effluent with good water

Dilution level	Number of productive tillers			Total dry matter production								
				30 DAS			60 DAS			90 DAS		
	1999- 2000	2000- 2001	Pooled	1999- 2000	2000- 2001	Pooled	1999- 2000	2000- 2001	Pooled	1999- 2000	2000- 2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	92.48	96.14	94.31	47.80	50.46	49.13	95.21	101.04	98.12	167.77	177.61	172.69
D ₂ – 1:10 (liquid effluent : good water)	96.90	104.24	100.57	49.60	51.74	50.67	97.98	106.89	102.43	177.89	192.63	185.26
D ₃ – 1:25 (liquid effluent : good water)	105.36	107.70	106.53	51.25	52.51	51.88	109.15	113.50	111.32	191.18	199.37	195.27
D ₄ – 1:50 (liquid effluent : good water)	117.21	119.59	118.40	53.41	54.66	54.03	120.53	123.70	122.11	210.78	215.44	213.11
D ₅ – Undiluted liquid effluent	35.10	36.08	35.59	36.60	37.93	37.26	58.91	60.63	59.77	90.16	92.37	91.26
D ₆ – Good water	114.24	116.04	115.14	52.05	53.10	52.57	117.60	120.65	119.12	206.92	209.70	208.31
S.E.m±	2.52	2.75	1.86	0.76	0.76	0.54	1.57	2.50	1.47	3.42	3.60	2.48
CD at 5%	7.84	8.55	5.49	2.36	2.36	1.59	4.88	7.77	4.37	10.64	11.20	7.32

DAS – Days after sowing

found on par with irrigation by good water. Whereas, irrigation by undiluted effluent recorded the lowest TDM production at all the stages (37.26, 59.77 and 91.26 at 30, 60, 90 DAS, respectively).

4.4.1.5.2 Dry matter accumulation in leaves (g/m row length) (Table 71)

Significantly higher dry matter accumulation (DMA) in leaf was observed in higher dilution level of 1:50 at 30, 60, 90 DAS (29.74, 49.40 and 43.10, respectively) over remaining dilution levels. While, significantly the lowest DMA in leaf was registered at irrigation by undiluted effluent (20.33, 18.08, 15.36 at 30, 60, 90 DAS, respectively).

4.4.1.5.3 Dry matter accumulation in stem (g/m row length) (Table 72)

Significant difference in DMA in stem was noticed due to dilution levels. At all the stages, significantly higher DMA in stem was recorded at higher dilution level of 1:50 (24.30, 50.30 and 74.60 at 30, 60, 90 DAS, respectively) over remaining dilution levels but was found on par with irrigation by good water. Irrigation by undiluted effluent recorded significantly the lowest DMA in stem irrespective of growth stages (16.93, 32.55 and 48.15 at 30, 60, 90 DAS, respectively).

4.4.1.5.4 Dry matter accumulation in ear (g/m row length) (Table 72)

Both at 60 and 90 DAS, significantly higher DMA in ear (22.41 and 95.40, respectively) was observed with 1:50 dilution level over the remaining ones. However, the next in order after 1:50 dilution level which found on par was irrigation by good water. Significantly the lowest DMA in ear was recorded with irrigation by undiluted effluent (9.14 and 27.75 at 60 and 90 DAS, respectively).

Table 71. Dry matter accumulation in leaf (g/m row length) at different growth stages in wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Dry matter accumulation in leaf									
	30 DAS			60 DAS			90 DAS			Pooled
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	
D ₁ – 1:5 (liquid effluent : good water)	27.12	28.52	27.82	38.32	40.72	39.52	33.41	35.89	34.65	
D ₂ – 1:10 (liquid effluent : good water)	28.20	28.53	28.36	40.10	43.54	41.82	36.10	39.14	37.62	
D ₃ – 1:25 (liquid effluent : good water)	28.50	29.30	28.90	43.02	45.94	44.48	37.28	42.02	39.65	
D ₄ – 1:50 (liquid effluent : good water)	29.35	30.12	29.74	48.71	50.10	49.40	42.50	43.71	43.10	
D ₅ – Undiluted liquid effluent	19.92	20.75	20.33	17.90	18.26	18.08	15.10	15.62	15.36	
D ₆ – Good water	28.65	29.80	29.22	47.36	48.74	48.05	41.70	42.34	42.02	
S.E.m±	0.63	0.79	0.51	0.95	1.17	0.76	0.72	1.12	0.67	
CD at 5%	1.96	2.46	1.50	2.95	3.64	2.24	2.24	3.50	1.98	

DAS – Days after sowing

Table 72. Dry matter accumulation in stem and ear (g/m row length) at different growth stages in wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Dry matter accumulation in stem												Dry matter accumulation in ear					
	30 DAS				60 DAS				90 DAS				60 DAS			90 DAS		
	1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled		1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ - 1:5 (liquid effluent : good water)	20.68	21.94	21.31		39.15	41.67	40.41		59.70	62.54	61.12		17.74	18.65	18.19	74.66	79.18	76.92
D ₂ - 1:10 (liquid effluent : good water)	21.40	23.21	22.31		39.60	43.06	41.33		62.65	67.87	65.26		18.73	20.29	19.51	79.14	85.62	82.36
D ₃ - 1:25 (liquid effluent : good water)	22.75	23.21	22.98		46.01	47.03	46.52		67.38	68.97	68.18		20.12	20.53	20.32	86.52	88.38	87.45
D ₄ - 1:50 (liquid effluent : good water)	24.06	24.54	24.30		49.72	50.88	50.30		73.83	75.37	74.60		22.10	22.72	22.41	94.45	96.36	95.40
D ₅ - Undiluted liquid effluent	16.68	17.18	16.93		31.96	33.14	32.55		47.80	48.51	48.15		9.05	9.23	9.14	27.26	28.24	27.75
D ₆ - Good water	23.40	24.10	23.75		48.90	49.51	49.20		72.20	73.26	72.73		21.34	22.40	21.87	93.02	94.10	93.56
S.E.m±	0.42	0.43	0.30		0.47	0.61	0.38		0.87	0.96	0.66		0.43	0.58	0.36	0.64	1.27	0.71
CD at 5%	1.31	1.34	0.90		1.46	1.90	1.13		2.70	2.98	1.95		1.34	1.80	1.06	1.99	3.95	2.09

DAS - Days after sowing

4.4.1.6 Days to 50 per cent heading (Table 73)

Days to 50 per cent heading was greatly influenced by dilution levels. Among different dilution levels, irrigation by undiluted effluent took significantly lesser days to 50 per cent heading (51.50) followed by lower dilution level of 1:5. Whereas, significantly higher number of days to 50 per cent heading (56.20) was recorded with irrigation by higher dilution level of 1:50 and was found on par with irrigation by good water, 1:50, 1:25 and 1:10 dilution levels.

4.4.2 Yield and yield parameters

4.4.2.1 Ear length (cm) (Table 73)

The different dilution levels brought significant change on length of ear. The lengthiest (10.30) and the shortest ears (4.59) were noticed at higher dilution level of 1:50 and irrigation by undiluted effluent, respectively. Whereas, remaining dilution levels were significantly differed with each other.

4.4.2.2 Ear weight (g) (Table 73)

Ear weight was varied significantly due to dilution levels. Significantly the lowest (1.64) and the highest (3.10) ear weights were recorded at 1:50 dilution level and irrigation by undiluted effluent, respectively. However, the dilution level of 1:50 and irrigation by good water were found on par with each other.

4.4.2.3 Number of grains per ear (Table 73)

Grain number per ear was significantly influenced by dilution levels. Irrigation by dilution level of 1:50 recorded significantly higher number of grains per ear of 54.43 as compared to remaining dilution levels but was found on par with irrigation by good water. Whereas,

significantly the lowest number of grains per ear (14.29) was recorded with irrigation by undiluted effluent.

4.4.2.4 Test weight (1000-grain weight) (Table 73)

The different dilution levels exerted significant variation on test weight. The highest test weight at 1:50 dilution level (40.98) was found to be significantly higher over rest of dilution levels except irrigation by good water. While, significantly the lowest test weight was recorded with irrigation by undiluted effluent (14.29).

4.4.2.5 Grain yield (q/ha) (Table 74 and Fig.15)

Grain yield was significantly influenced by dilution levels. Significantly higher grain yield (52.59) was recorded with irrigation by higher dilution level of 1:50 as compared to remaining dilution levels but was found on par with irrigation by good water. Whereas, significantly the lowest grain yield of 10.56 was recorded with irrigation by undiluted effluent.

4.4.2.6 Straw yield (q/ha) (Table 74 and Fig.15)

Straw yield differed significantly due to different dilution levels. The straw yield was significantly higher at higher dilution level of 1:50 (67.23) over other dilution levels and was found statistically on par with irrigation by good water. Whereas, significantly the lowest straw yield (20.39) was recorded with irrigation by undiluted effluent.

4.4.2.7 Harvest index (Table 74)

Harvest index (HI) showed significant variation due to irrigation by different dilution levels. Significantly higher harvest index of 0.438 was

Table 73. Days to 50 per cent heading, ear length (cm), ear weight (g), number of grains per ear and test weight (1000-grain weight) in wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Days to 50 per cent heading			Ear length			Ear weight			Number of grains per ear			1000-grain weight		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ - 1:5 (liquid effluent : good water)	54.30	55.00	54.60	8.05	8.56	8.30	2.45	2.57	2.51	42.42	44.98	43.70	32.15	34.09	33.12
D ₂ - 1:10 (liquid effluent : good water)	55.30	55.40	55.35	8.53	9.25	8.89	2.71	2.94	2.82	44.98	48.74	46.86	34.43	37.29	35.86
D ₃ - 1:25 (liquid effluent : good water)	54.80	55.80	55.30	9.32	9.48	9.40	2.87	2.93	2.90	48.68	49.72	49.20	37.70	38.60	38.15
D ₄ - 1:50 (liquid effluent : good water)	56.00	56.40	56.20	10.20	10.41	10.30	3.07	3.13	3.10	53.90	54.96	54.43	40.50	41.46	40.98
D ₅ - Undiluted liquid effluent	51.30	51.60	51.50	4.54	4.65	4.59	1.62	1.66	1.64	18.11	18.48	18.29	14.15	14.43	14.29
D ₆ - Good water	55.90	56.40	56.15	10.01	10.13	10.07	3.00	3.04	3.02	52.71	53.35	53.03	39.74	40.22	39.98
S.E.m±	0.84	0.59	0.52	0.13	0.11	0.08	0.09	0.13	0.08	0.97	0.59	0.58	0.67	0.93	0.57
CD at 5%	2.61	1.83	1.53	0.40	0.34	0.24	0.28	0.40	0.23	3.01	1.83	1.71	2.08	2.89	1.68

Table 74. Grain yield (q/ha), straw yield (q/ha) and harvest index (HI) of wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Grain yield			Straw yield			Harvest index		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	41.05	43.47	42.26	58.50	61.38	59.94	0.412	0.416	0.414
D ₂ – 1:10 (liquid effluent : good water)	43.50	47.12	45.31	59.35	64.29	61.82	0.417	0.427	0.422
D ₃ – 1:25 (liquid effluent : good water)	46.95	48.25	47.60	62.74	64.22	63.48	0.425	0.429	0.428
D ₄ – 1:50 (liquid effluent : good water)	52.13	53.05	52.59	66.90	67.90	67.23	0.438	0.439	0.438
D ₅ – Undiluted liquid effluent	10.45	10.67	10.56	20.20	20.58	20.39	0.340	0.341	0.340
D ₆ – Good water	51.01	51.57	51.29	65.48	66.20	65.84	0.437	0.438	0.438
S.E.m±	0.68	0.75	0.51	1.03	1.08	0.75	0.007	0.008	0.005
CD at 5%	2.11	2.33	1.50	3.20	3.36	2.21	0.022	0.025	0.016

LEGEND

Dilution levels

D₁ - 1:5 (liquid effluent : good water)

D₂ - 1:10 (liquid effluent:good water)

D₃ - 1:25 (liquid effluent: good water)

D₄ - 1:50 (liquid effluent:good water)

D₅ - Undiluted liquid effluent

D₆ - Good water.

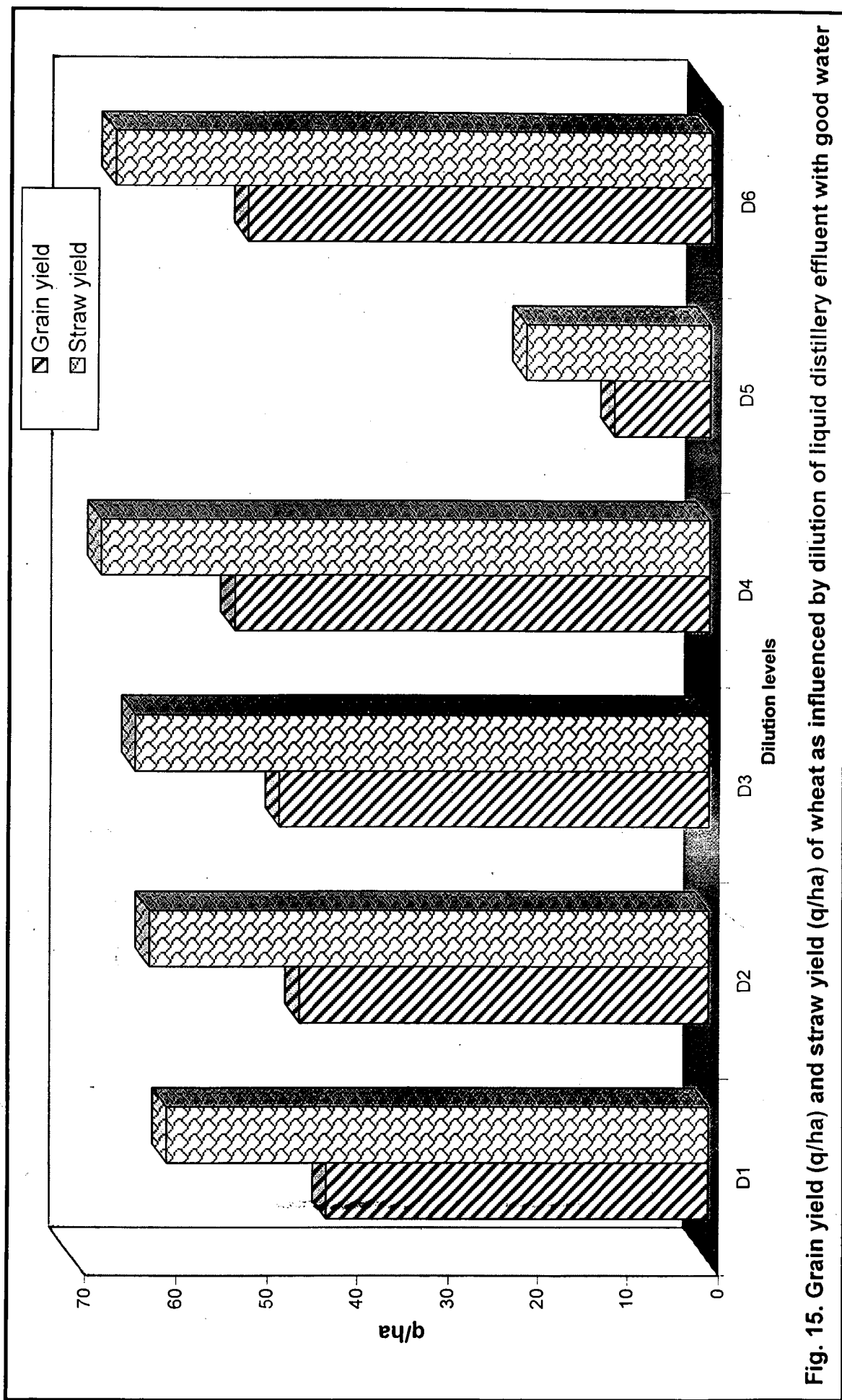


Fig. 15. Grain yield (q/ha) and straw yield (q/ha) of wheat as influenced by dilution of liquid distillery effluent with good water

recorded at higher dilution level of 1:50 which was found on par with other dilution levels except irrigation by lower dilution level of 1:5 and undiluted effluent.

4.4.3 Quality parameters

4.4.3.1 Protein (%) (Table 75)

The different dilution levels brought significant variation on protein content in grains. Significantly higher protein content was recorded with irrigation by undiluted effluent (13.26) over rest of dilution levels however it was found on par with lower dilution levels of 1:5 and 1:10. The significant lowest protein content was recorded irrigation by good water (12.30) further found on par with higher dilution level of 1:50.

4.4.3.2 Sedimentation value (ml) (Table 75)

Sedimentation value differed significantly due to dilution levels. Irrigation by undiluted effluent recorded significantly higher sedimentation value (25.85) but was found on par with dilution levels of 1:5, 1:10 and 1:25. Whereas, irrigation by good water recorded lowest sedimentation value (24.73) followed by dilution levels of 1:50, 1:25 and 1:10.

4.4.3.3 Wet gluten content (%) (Table 75)

Different dilution levels resulted significant variation on wet gluten content. Significantly higher wet gluten content was recorded with irrigation by undiluted effluent (29.52) followed by 1:5 and 1:10 and all these level were found on par among themselves. Whereas irrigation by good water recorded the lowest wet gluten content in grains (28.23) followed by higher dilution level of 1:50.

4.4.3.4 Dry gluten content (%) (Table 75)

The dilution levels brought significant influence on dry gluten content. Significantly higher dry gluten content was recorded with irrigation by undiluted effluent (9.06) which was found significantly superior to other dilution levels except lower dilution levels of 1:5 and 1:10. Significantly the lowest dry gluten content was recorded with irrigation by undiluted effluent (8.69) followed by higher dilution level of 1:50.

4.4.4 Nutrient contents in plant

4.4.4.1 Nutrient contents in plant at anthesis

4.4.4.1.1 Nitrogen (%) (Table 76)

Nitrogen content was differed significantly due to dilution levels. Significantly higher nitrogen content was recorded with irrigation by undiluted effluent (2.62) over rest of dilution levels. Whereas, significantly the lowest nitrogen content was recorded with irrigation by good water (2.29) followed by higher dilution level of 1:50.

4.4.4.1.2 Phosphorus (%) (Table 76)

The dilution levels varied significantly for phosphorus content. Significantly higher phosphorus content (0.251) was recorded with irrigation by undiluted effluent over rest of dilution levels. While, significantly lower phosphorus content was recorded with irrigation by good water (0.198).

4.4.4.1.3 Potassium (%) (Table 76)

Potassium content in plant differed significantly due to dilution levels. Significantly highest potassium content was recorded at irrigation by undiluted effluent (3.26) over other dilution levels. Whereas,

Table 75. Protein (%), sedimentation value (ml), wet gluten (%) and dry gluten (%) in wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Protein			Sedimentation value			Wet gluten			Dry gluten		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	13.15	13.26	13.20	25.06	26.40	25.73	28.95	29.81	29.38	8.91	9.13	9.02
D ₂ – 1:10 (liquid effluent : good water)	13.02	13.03	13.02	25.28	25.32	25.30	28.14	29.64	28.90	8.78	9.01	8.89
D ₃ – 1:25 (liquid effluent : good water)	12.80	12.81	12.80	24.90	25.01	24.95	28.20	28.76	28.48	8.73	8.83	8.78
D ₄ – 1:50 (liquid effluent : good water)	12.41	12.43	12.42	24.79	24.87	24.82	28.26	28.44	28.35	8.68	8.72	8.70
D ₅ – Undiluted liquid effluent	13.24	13.29	13.26	25.28	26.42	25.85	29.35	29.69	29.52	8.96	9.14	9.06
D ₆ – Good water	12.28	12.32	12.30	24.64	24.82	24.73	27.47	28.59	28.23	8.68	8.71	8.69
S.E.m±	0.16	0.18	0.12	0.41	0.47	0.31	0.46	0.53	0.35	0.10	0.15	0.09
CD at 5%	0.49	0.56	0.35	1.27	1.46	0.91	1.43	1.65	1.03	0.31	0.46	0.26

Table 76. Nitrogen, phosphorus and potassium contents (%) in wheat at anthesis as influenced by dilution of liquid distillery effluent with good water

Dilution level	Nitrogen			Phosphorus			Potassium		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	2.45	2.56	2.51	0.230	0.250	0.240	3.02	3.29	3.16
D ₂ – 1:10 (liquid effluent : good water)	2.38	2.48	2.43	0.225	0.240	0.231	2.95	3.00	2.98
D ₃ – 1:25 (liquid effluent : good water)	2.32	2.45	2.39	0.210	0.225	0.217	2.90	2.98	2.94
D ₄ – 1:50 (liquid effluent : good water)	2.30	2.42	2.36	0.208	0.210	0.209	2.85	2.93	2.89
D ₅ – Undiluted liquid effluent	2.58	2.65	2.62	0.245	0.257	0.251	3.18	3.39	3.26
D ₆ – Good water	2.25	2.32	2.29	0.194	0.202	0.198	2.81	2.95	2.89
S.E.m±	0.03	0.04	0.03	0.002	0.004	0.002	0.04	0.04	0.03
CD at 5%	0.09	0.12	0.09	0.006	0.012	0.006	0.12	0.12	0.09

significantly the lowest potassium content (2.89) in plant was recorded with irrigation good however it was found on par with other dilution levels of 1:50, 1:25 and 1:10.

4.4.4.2 Nutrient contents in plant at harvest and their total uptake

4.4.4.2.1 Nitrogen contents (%) in grain and straw and total nitrogen uptake (kg/ha) (Table 77 and Fig.16)

Nitrogen contents differed significantly due to dilution levels in both grain and straw. Significantly the highest nitrogen content in grain was recorded with irrigation by undiluted effluent (2.12) which was found on par with all the dilution levels except higher dilution level of 1:50 and irrigation by good water. Whereas, significantly higher nitrogen in stover (0.62) was recorded with irrigation by undiluted effluent over other dilution levels and was found on par with lower dilution level of 1:5. While, irrigation by good water recorded significantly lower nitrogen content in stover (0.55) followed by 1:50 dilution level.

Significantly higher total nitrogen uptake of 144.21 was recorded with higher dilution level of 1:50 over other dilution levels. Whereas, significantly lowest total uptake (32.89) was recorded with irrigation by undiluted effluent.

4.4.4.2.2 Phosphorus contents (%) in grain and straw and total phosphorus uptake (kg/ha) (Table 78 and Fig.16)

The dilution levels did not bring significant influence on phosphorus content in grain and straw.

Total uptake of phosphorus by crop was significantly influenced by dilution levels. Significantly the highest total phosphorus uptake was recorded with higher dilution level of 1:50 (43.35) however it was found

Table 77. Nitrogen contents (%) in grain and straw and total uptake (kg/ha) by wheat at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Nitrogen content						Total uptake		
	Grain			Straw					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	2.10	2.12	2.11	0.60	0.62	0.61	121.30	130.21	125.75
D ₂ – 1:10 (liquid effluent : good water)	2.08	2.08	2.08	0.58	0.59	0.58	124.90	135.94	130.42
D ₃ – 1:25 ((liquid effluent : good water)	2.05	2.05	2.05	0.57	0.59	0.58	132.01	136.80	134.40
D ₄ – 1:50 (liquid effluent : good water)	1.98	1.99	1.98	0.55	0.56	0.56	142.65	145.77	144.21
D ₅ –Undiluted liquid effluent	2.12	2.13	2.12	0.61	0.64	0.62	31.80	33.99	32.89
D ₆ – Good water	1.96	1.97	1.96	0.54	0.56	0.55	135.34	138.66	137.00
S.Em±	0.05	0.04	0.03	0.008	0.009	0.006	2.60	1.74	1.57
CD at 5%	0.15	0.12	0.09	0.025	0.028	0.018	8.08	5.41	4.63

Table 78. Phosphorus contents (%) in grain and straw and total uptake (kg/ha) by wheat at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Phosphorus content						Total uptake		
	Grain			Straw					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	0.62	0.63	0.62	0.20	0.21	0.20	37.15	40.28	38.71
D ₂ – 1:10 (liquid effluent : good water)	0.61	0.62	0.61	0.19	0.20	0.19	37.81	42.07	39.94
D ₃ – 1:25 ((liquid effluent : good water)	0.61	0.62	0.61	0.18	0.19	0.18	39.93	42.11	41.02
D ₄ – 1:50 (liquid effluent : good water)	0.59	.061	0.60	0.17	0.18	0.17	42.13	44.58	43.35
D ₅ –Undiluted liquid effluent	0.63	0.65	0.64	0.21	0.23	0.22	10.82	11.78	11.30
D ₆ – Good water	0.59	0.60	0.59	0.16	0.18	0.17	40.58	42.86	41.72
S.Em±	0.03	0.04	0.02	0.03	0.03	0.02	1.90	2.11	1.42
CD at 5%	NS	NS	NS	NS	NS	NS	5.91	6.56	4.19

NS – Non significant

on par with all the dilution levels except irrigation by lower dilution level of 1:5 and undiluted effluent.

4.4.4.2.3 Potassium contents (%) in grain and straw and total potassium uptake (kg/ha) (Table 79 and Fig.16)

Potassium contents in grain and straw differed significantly due to dilution levels. Significantly higher potassium contents in grain and straw was recorded with irrigation by undiluted effluent however it was found on par with lower dilution levels of 1:5 and 1:10. Whereas, significantly the lowest total potassium uptake was recorded with irrigation by undiluted effluent (28.31).

4.4.4.2.4 Zinc contents (ppm) in grain and straw and total zinc uptake (kg/ha) (Table 80)

Dilution levels did not bring significant influence on zinc content in grain and straw. However, total uptake of zinc by crop differed significantly. Significantly higher total uptake of zinc (0.285) was recorded with higher dilution level of 1:50 however it was found on par with irrigation by good water and 1:25 dilution level. Whereas, significantly the lowest total zinc uptake (0.076) was recorded with irrigation by undiluted effluent.

4.4.4.2.5 Copper contents (ppm) in grain and straw and total copper uptake (kg/ha) (Table 80)

Neither in grain nor in straw, copper content differed significantly due to variation in dilution levels. However, there was significant variation on total copper uptake. Significantly the highest total copper uptake (0.237) was recorded with higher dilution level of 1:50 and was

Table 79. Potassium contents (%) in grain and straw and total uptake (kg/ha) by wheat at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Potassium content						Total uptake		
	Grain			Straw					
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	0.342	0.358	0.350	1.17	1.21	1.19	82.48	89.83	86.15
D ₂ – 1:10 (liquid effluent : good water)	0.340	0.353	0.346	1.13	1.19	1.16	82.85	92.13	87.49
D ₃ – 1:25 ((liquid effluent : good water)	0.338	0.342	0.340	1.14	1.16	1.15	97.39	90.99	89.19
D ₄ – 1:50 (liquid effluent : good water)	0.326	0.331	0.328	1.11	1.12	1.11	91.25	94.99	93.12
D ₅ –Undiluted liquid effluent	0.351	0.357	0.354	1.19	1.22	1.20	27.71	28.92	28.31
D ₆ – Good water	0.322	0.328	0.325	1.09	1.11	1.10	87.79	90.39	89.09
S.Em±	0.006	0.008	0.005	0.03	0.03	0.02	1.67	1.83	1.24
CD at 5%	0.018	0.025	0.015	0.09	0.09	0.06	5.19	5.69	3.65

LEGEND

Dilution levels

D₁ - 1:5 (liquid effluent : good water)

D₂ - 1:10 (liquid effluent:good water)

D₃ - 1:25 (liquid effluent: good water)

D₄ - 1:50 (liquid effluent:good water)

D₅ - Undiluted liquid effluent

D₆ - Good water.

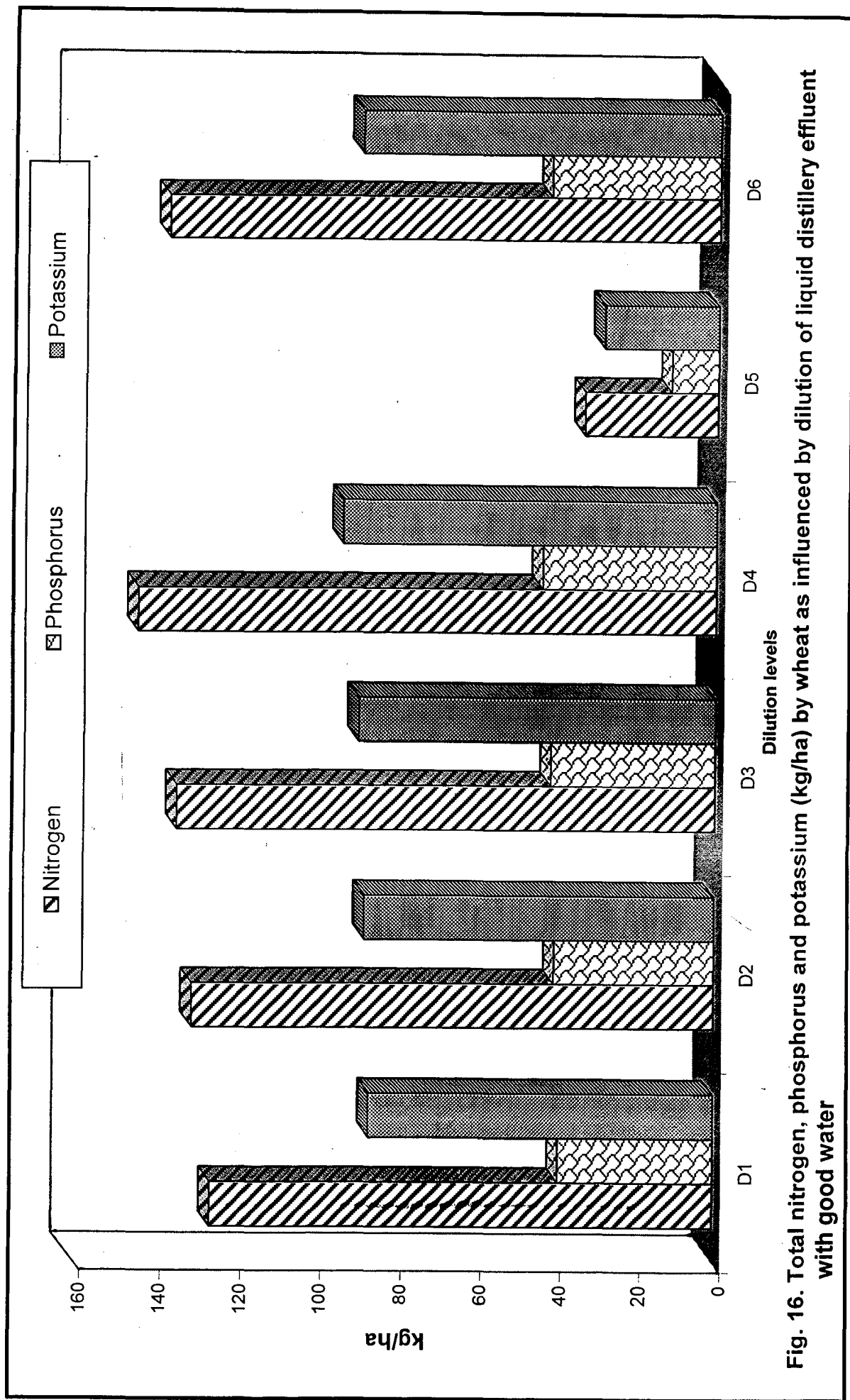


Fig. 16. Total nitrogen, phosphorus and potassium (kg/ha) by wheat as influenced by dilution of liquid distillery effluent with good water

Table 80. Zinc and copper contents (ppm) in grain and straw and total zinc and copper uptake (kg/ha) by wheat at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Zinc							Copper						
	Zinc content				Total uptake			Copper content				Total uptake		
	Grain		Straw		1999-2000	2000-2001	Pooled	Grain		Straw		1999-2000	2000-2001	Pooled
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001
D ₁ - 1:5 (liquid effluent : good water)	23.80	24.24	24.05	24.15	24.89	24.52	0.239	0.257	0.248	19.82	20.34	20.08	20.71	0.200
D ₂ - 1:10 (liquid effluent : good water)	23.57	24.19	23.88	23.92	24.68	24.30	0.244	0.271	0.257	19.76	20.20	19.98	20.58	0.206
D ₃ - 1:25 (liquid effluent : good water)	23.20	23.64	23.42	23.73	24.09	23.91	0.258	0.268	0.263	19.60	19.82	19.71	20.39	0.219
D ₄ - 1:50 (liquid effluent : good water)	23.06	24.46	23.26	23.68	24.01	23.84	0.278	0.292	0.285	19.57	19.67	19.62	20.21	0.236
D ₅ - Undiluted liquid effluent	24.15	24.43	24.29	24.64	24.95	24.79	0.075	0.077	0.076	20.15	20.47	20.31	20.89	0.063
D ₆ - Good water	23.08	23.32	23.20	23.72	23.80	23.76	0.272	0.277	0.274	19.34	19.46	19.40	20.17	0.229
S.E.m±	0.68	0.72	0.50	1.13	1.19	0.82	0.010	0.013	0.008	0.94	0.92	0.66	1.02	0.005
CD at 5%	NS	NS	NS	NS	NS	NS	0.031	0.040	0.024	NS	NS	NS	NS	0.015

NS - Non significant

found on par with all dilution levels except 1:5 dilution level and irrigation by undiluted effluent and good water.

4.4.4.2.6 Iron contents (ppm) in grain and straw and total iron uptake (kg/ha) (Table 81)

Iron contents in grain and straw was not influenced significantly by dilution levels. Whereas, significantly higher total uptake of iron (2.39) was recorded with higher dilution level of 1:50 over other dilution levels. Whereas, irrigation by undiluted effluent recorded significantly the lowest total iron uptake (0.64).

4.4.4.2.7 Manganese contents (ppm) in grain and straw and total manganese uptake (kg/ha) (Table 81)

The dilution levels could not bring significant variation either in grain or in straw however the total manganese uptake varied significantly.

Significantly the highest total manganese uptake was recorded with irrigation by higher dilution level of 1:50 (0.938) over remaining dilution levels. Whereas, significantly the lowest total manganese uptake (0.266) was recorded with irrigation by undiluted effluent.

4.4.5 Physico-chemical properties of soil

4.4.5.1 Physical properties

4.4.5.1.1 Bulk density (Mg/m^3) (Table 82)

Bulk density varied significantly due to dilution levels. Significantly the lowest bulk density (1.38) was recorded with irrigation by undiluted effluent however it was found on par with dilution levels of 1:5, 1:10 and

Table 81. Iron and manganese contents (ppm) in grain and straw and total iron and manganese uptake (kg/ha) by wheat at harvest as influenced by dilution of liquid distillery effluent with good water

Dilution level	Iron						Manganese											
	Iron content			Total uptake			Manganese content			Total uptake								
	Grain			Straw			Grain			Straw								
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled						
D ₁ – 1:5 (liquid effluent : good water)	178.78	183.66	181.22	217.78	222.40	220.09	2.01	2.16	2.08	49.21	51.47	50.34	101.10	104.28	102.69	0.793	0.862	0.827
D ₂ – 1:10 (liquid effluent : good water)	178.12	182.22	180.17	217.03	222.19	219.61	2.06	2.29	2.17	49.15	50.96	50.05	100.92	103.28	102.10	0.812	0.903	0.857
D ₃ – 1:25 (liquid effluent : good water)	177.96	179.34	178.65	215.53	219.89	217.71	2.18	2.28	2.23	49.12	50.10	49.61	100.49	102.53	101.51	0.860	0.902	0.881
D ₄ – 1:50 (liquid effluent : good water)	176.68	178.18	177.43	214.82	217.62	216.22	2.36	2.42	2.39	48.83	49.59	49.21	100.36	102.40	101.38	0.924	0.952	0.938
D ₅ –Undiluted liquid effluent	180.93	184.27	182.60	220.19	222.61	221.40	0.63	0.65	0.64	49.85	51.63	50.74	102.86	104.22	103.54	0.263	0.269	0.266
D ₆ – Good water	176.10	177.60	176.85	214.16	216.74	215.45	2.30	2.35	2.32	48.95	49.33	49.14	100.87	101.63	101.25	0.909	0.924	0.916
S.E.m±	4.41	4.50	3.16	4.91	5.09	3.54	0.025	0.034	0.021	1.56	1.73	1.17	3.32	3.56	2.43	0.017	0.016	0.012
CD at 5%	NS	NS	NS	NS	NS	NS	0.078	0.106	0.062	NS	NS	NS	NS	NS	NS	0.053	0.049	0.035

1:25. Whereas, significantly the highest bulk density was recorded with irrigation by good water (1.52) followed by higher dilution level of 1:50.

4.4.5.2 Chemical properties

4.4.5.2.1 Soil reaction (pH) (Table 82)

Soil reaction varied significantly due to variation in dilution levels. Irrigation by undiluted effluent recorded significantly higher soil pH (7.92) over remaining dilution levels however it was found on par with lower dilution level of 1:5. Whereas, significantly the lowest soil pH (6.94) was recorded with irrigation by good water.

4.4.5.2.2 Electrical conductivity (dSm^{-1}) (Table 82)

The different dilution levels exhibited significant influence on electrical conductivity of soil. The electrical conductivity of soil increased significantly with increase in concentration of effluent in the dilution levels and significantly highest electrical conductivity was recorded with irrigation by undiluted effluent (1.13) followed by lower dilution levels of 1:5 and 1:10. Whereas, significantly the lowest electrical conductivity of soil was recorded with irrigation by good water (0.50).

4.4.5.2.3 Organic carbon (%) (Table 82)

Different dilution levels exhibited significant influence on soil organic carbon. With the increasing concentration of effluent in dilution, there was gradual increase in organic carbon content of soil and it was significantly higher at irrigation by undiluted effluent (0.52) over other dilution levels but was found on par with lower dilution level of 1:5. Whereas, significantly the lowest organic carbon content (0.47) was recorded with irrigation by undiluted effluent followed by higher dilution level of 1:50.

Table 82. Bulk density (Mg/m^3), soil reaction (pH), electrical conductivity (EC, dSm^{-1}) and organic carbon (OC, %) in soil after harvest of wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Bulk density			pH		EC			OC	
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	
D ₁ – 1:5 (liquid effluent : good water)	1.44	1.41	1.42	7.80	7.91	7.85	0.88	0.96	0.92	0.51
D ₂ – 1:10 (liquid effluent : good water)	1.46	1.43	1.44	7.68	7.70	7.69	0.80	0.89	0.84	0.50
D ₃ – 1:25 (liquid effluent : good water)	1.49	1.45	1.47	7.51	7.68	7.60	0.59	0.63	0.61	0.49
D ₄ – 1:50 (liquid effluent : good water)	1.52	1.50	1.51	7.12	7.17	7.14	0.53	0.60	0.56	0.48
D ₅ – Undiluted liquid effluent	1.41	1.36	1.38	7.87	7.98	7.92	1.10	1.16	1.13	0.52
D ₆ – Good water	1.52	1.52	1.52	6.95	6.93	6.94	0.49	0.51	0.50	0.47
S.E.m $\pm$	0.05	0.07	0.04	0.09	0.07	0.06	0.04	0.04	0.03	0.005
CD at 5%	0.15	0.22	0.12	0.28	0.22	0.18	0.12	0.12	0.12	0.015

4.4.5.2.4 Nutrient status in soil

4.4.5.2.4.1 Available nitrogen (kg/ha) (Table 83 and Fig.17)

Variation in dilution levels caused significant variation on available nitrogen content of soil. Significantly higher available nitrogen was recorded with irrigation by undiluted effluent (421.46) as compared to other dilution levels. While, significantly the lowest available nitrogen was recorded with irrigation by good water (217.17).

4.4.5.2.4.2 Available phosphorus (kg/ha) (Table 83 and Fig. 17)

Different dilution levels brought significant influence on available phosphorus content of soil. Irrigation by undiluted effluent recorded significantly higher phosphorus content (53.05) over other dilution levels except lower dilution level of 1:5. Whereas, significantly lower available phosphorus content (30.51) was recorded with irrigation by good water followed by higher dilution level of 1:50.

4.4.5.2.4.3 Available potassium (kg/ha) (Table 83 and Fig.17)

Available potassium was significantly differed due to different dilution levels. Significantly higher available potassium (669.51) was recorded with irrigation by undiluted effluent over other dilution levels. Whereas, significantly the lowest available potassium content (378.88) was recorded with irrigation by good water followed by dilution level of 1:50.

4.4.5.2.4.4 DTPA extractable (available) micronutrients in soil (ppm) (Table 84)

4.4.5.2.4.4.1 Zinc

The variation in dilution levels brought significant difference on zinc content of soil. Irrigation by undiluted effluent recorded significantly

Table 83. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Available nitrogen			Available phosphorus			Available potassium		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	360.35	367.01	363.68	37.40	40.20	38.80	530.65	538.29	534.47
D ₂ – 1:10 (liquid effluent : good water)	324.96	334.98	329.97	34.01	37.05	35.53	490.748	499.54	495.16
D ₃ – 1:25 ((liquid effluent : good water)	286.74	295.66	291.20	32.34	35.01	33.67	455.28	465.98	460.63
D ₄ – 1:50 (liquid effluent : good water)	259.01	264.29	261.64	31.03	32.69	31.36	426.30	432.54	429.42
D ₅ – Undiluted liquid effluent	419.54	424.38	421.46	51.79	53.51	53.15	658.16	680.86	669.51
D ₆ – Good water	218.14	216.20	217.17	30.89	30.13	30.51	380.93	376.84	378.88
S.Em±	7.03	8.43	5.47	1.94	2.22	1.47	9.85	10.76	7.29
CD at 5%	21.86	26.22	16.14	6.03	6.90	4.34	30.63	33.46	21.50

LEGEND

Dilution levels

D₁ - 1:5 (liquid effluent : good water)

D₂ - 1:10 (liquid effluent:good water)

D₃ - 1:25 (liquid effluent: good water)

D₄ - 1:50 (liquid effluent:good water)

D₅ - Undiluted liquid effluent

D₆ - Good water.

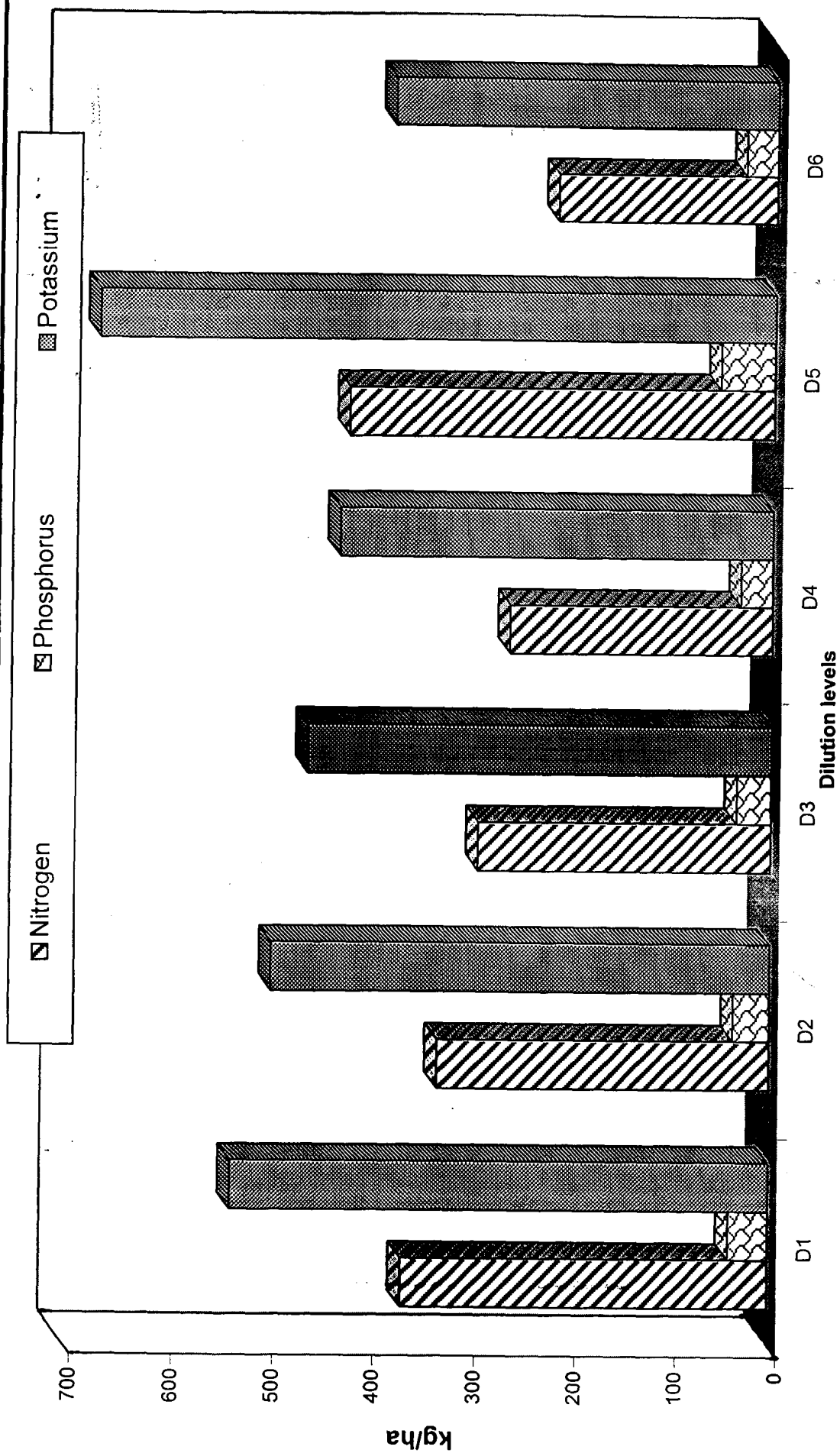


Fig. 17. Available nitrogen, phosphorus and potassium (kg/ha) in soil after harvest of wheat as influenced by dilution of liquid distillery effluent with good water

higher zinc content (3.80) over other dilution levels. While, irrigation by good water recorded significantly lower zinc content (2.08) followed by higher dilution level of 1:50.

4.4.5.2.4.4.2 Copper

Copper content of soil varied significantly due to variation in dilution levels. Significantly higher copper content was recorded with irrigation by undiluted effluent (2.21) over other dilution levels but was found on par with 1:5 dilution level. Whereas, significantly lower copper content was recorded with irrigation by good water (1.77) followed by higher dilution level of 1:50.

4.4.5.2.4.4.3 Iron

Dilution levels exerted significant influence on iron content of soil. Significantly higher iron content was recorded with irrigation by undiluted effluent (11.43) over other dilution levels. While, significantly the lowest iron content was recorded with irrigation by good water (4.95) followed by dilution level of 1:50.

4.4.5.2.4.4.4 Manganese

Dilution levels exhibited significant influence on manganese content of soil. Maximum content of manganese (9.32) was recorded with irrigation by undiluted effluent which found significantly superior to all dilution levels except lower dilution level of 1:5. Whereas, significantly the lowest manganese content was recorded with irrigation by good water (8.84).

Table 84. DTPA extractable zinc, copper, iron and manganese contents (ppm) in soil after harvest of wheat as influenced by dilution of liquid distillery effluent with good water

Dilution level	Zinc			Copper			Iron			Manganese		
	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	3.40	3.66	3.53	2.08	2.12	2.10	8.98	10.02	9.50	9.03	9.34	9.18
D ₂ – 1:10 (liquid effluent : good water)	3.21	3.37	3.29	1.99	2.11	2.05	7.10	8.08	7.59	8.96	9.22	9.09
D ₃ – 1:25 (liquid effluent : good water)	3.12	3.20	3.16	1.87	1.91	1.89	5.20	5.72	5.46	8.92	9.12	9.02
D ₄ – 1:50 (liquid effluent : good water)	2.94	3.01	2.97	1.80	1.82	1.81	4.95	5.07	5.01	8.89	9.07	8.98
D ₅ – Undiluted liquid effluent	3.78	3.82	3.80	2.17	2.23	2.21	10.92	11.94	11.43	9.07	9.57	9.32
D ₆ – Good water	2.09	2.07	2.08	1.78	1.75	1.77	4.98	4.92	4.95	8.89	8.80	8.84
S.E.m±	0.06	0.08	0.05	0.05	0.06	0.04	0.12	0.14	0.09	0.08	0.09	0.06
CD at 5%	0.18	0.25	0.15	0.15	0.18	0.12	0.37	0.43	0.27	0.25	0.28	0.18

The higher dilution level of 1:50 obtained the highest gross return (46,106) which was closely followed by irrigation with good water (44,982). Again, 1:50 dilution level recorded the highest net returns (34,232) and next in the order was irrigation by good water (33,359). Whereas, negative net returns (-1001) and B:C ratio (-0.09) were recorded with irrigation by undiluted effluent.

Table 85 : Economics as influenced by dilution of liquid distillery effluent with good water in wheat

Nitrogen substitution level	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)			Net returns (Rs./ ha)			B:C ratio		
		1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled	1999-2000	2000-2001	Pooled
D ₁ – 1:5 (liquid effluent : good water)	12532	36350	38459	38585	23818	25927	26053	1.90	2.07	1.98
D ₂ – 1:10 (liquid effluent : good water)	12331	38361	41553	40737	26030	29222	28406	2.11	2.34	2.22
D ₃ – 1:25 (liquid effluent : good water)	12095	41324	2453	42309	29229	30358	30214	2.41	251	2.46
D ₄ – 1:50 (liquid effluent : good water)	11874	45718	46514	46106	33844	34540	34232	2.85	2.91	2.88
D ₅ – Undiluted liquid effluent	10672	9572	9771	9671	-991	-1010	-1001	-0.09	-0.09	-0.09
D ₆ – Good water	11623	44737	45228	44982	33179	33540	33359	2.85	2.88	2.86
S.E.m±		1052	1249	814	996	1037	719	0.09	0.10	0.07
CD at 5%		3272	3884	2401	3097	3225	2121	0.28	0.31	0.21

Discussion

V. DISCUSSION

Minimizing the environmental pollution is assuming increasingly greater importance with the rapid growth of population and the fast rise in the development of industries. The safe disposal of the industrial effluents has become a very important problem of concern. Since the quantity of the effluents at times is very large and the availability of fresh waters for irrigation is scarce, it seems that one of the alternatives to dispose of effluents is to use them for irrigation. Obviously the questions arise; whether the particular effluent is suitable for irrigation after some treatment or it is unsuitable for irrigation. This will be different for different type of effluents. The probable uses of distillery effluent for agronomical purposes are (a) as a manure, (b) for the preparation of mixed fertilizer and (c) as an irrigation water. In certain areas the scarcity of the water has forced the farmers to use the effluent as a substitute of irrigation water but over the years the use of this has led to realization of its manurial potential also. Distillery effluent contain considerable amount of nutrients. Therefore, effluent if utilized for crop production can approve to be a good source of nutrients and water and would reduce the investment on fertilizer. Keeping this in mind, the present investigation was undertaken and results are discussed in this chapter.

5.1 Effect of weather on crop growth and yield

Environment is the foster parent of plants and the fluctuations in weather conditions truly reflect on crop growth and development and ultimately on expected yield. Eghball *et al.* (1995) reported that the management practices may in some cases reduce temporal variability but

in other cases management practices have little effect on the year to year variability of crop yields. The year to year fluctuation is primarily a result of variable weather. The weather parameters such as maximum and minimum temperatures and relative humidity were conducive to the crop during the growth period.

Sri Lakshmi Narayana Distillery Unit, Garag, is situated in Northern Transitional Zone of Karnataka (Zone No.8). This place lacks the facilities for recording the meteorological observations, since, it is a factory meant for alcohol production. Therefore, the climatic data was obtained from the nearest Main Research Station, Dharwad which is situated 8 kms away from SLND, Garag.

In general, yield of both crops were higher during second year (2000-2001) compared to first year (1999-2000) which could be ascribed to better climatic conditions especially low maximum temperature (29.60°C in Nov. to 35.01°C in Feb.) and low minimum temperature (16.0°C in Nov. 17.50°C in Feb.) in second year cropping season. Whereas, high maximum temperature, high minimum temperature and high relative humidity in first year during cropping season might have reduced the crop yield.

5.2 Experiment 1 : Studies on use of distillery effluent (Solid and Liquid effluents) as a source of nitrogen on the performance of *rabi* maize

5.2.1 Effect of nitrogen substitution with solid and liquid distillery effluents on growth and yield

It is a basic biological principle that quantity and quality of growth made by a plant are controlled by its genetic potentialities and the

environment acting through its internal physiological and biochemical processes and conditions. The only way in which environmental factors such as moisture, temperature and mineral nutrients can affect growth is by affecting internal processes and conditions. The mineral nutrition of crop plants is the major factor which limits the crop growth and yields are more often limited by deficiency of nitrogen than any other nutrient. Hence, application of nitrogen to crops is necessary for getting higher yield (Reddy and Prasad, 1977).

The production of photosynthates and their translocation to sink depends upon mineral nutrition which is supplied either by soil or through foliar application. Most of the photosynthetic pathways are dependent on enzymes and co-enzymes which are synthesized by mineral nutrient elements such as nitrogen, phosphorus and potassium. Nitrogen is an integral part of chlorophyll and precursor for many enzymes, co-enzymes and amino acids and plays a vital role in plant metabolism. Nitrogen supply is one of the most important factors that determines the growth of the crop.

Nitrogen substitution through application of distillery effluents significantly influenced the grain yield of maize (Table 15). Significantly the highest grain yield in maize (70.17 q/ha) was recorded in nitrogen substitution level of 50 per cent through solid effluent plus 50 per cent through inorganic source (S₅). However, S₅ was found on par with nitrogen substitution levels of 25 per cent through solid effluent plus 75 per cent through inorganic source (S₇) and 100 per cent through inorganic source (S₁₀). Further, grain yield at S₁₀ (69.40 q/ha) was found on par with nitrogen substitution levels of 25 per cent through inorganic source (S₆) and 50 per cent through liquid effluent plus 50 per cent

through inorganic source (S₄). Whereas, significantly the lowest grain yield (62.81 q/ha) was recorded in substitution level which received 25 per cent through solid effluent plus 75 per cent through liquid effluent (S₉) and this accounted to 10.49 per cent lesser than 100 per cent substitution through inorganic source (S₁₀). However, grain yield at S₉ was on par with other nitrogen substitution levels which substituted 100 per cent through solid and liquid distillery effluents either in combination or individually. These results suggested that 100 per cent substitution through distillery effluents resulted in significantly lower grain yield than combination of distillery effluents with inorganic source. Results also revealed that small amount of chemical fertilizer along with distillery effluents is required to supplement the demand of the crop nitrogen in the initial stage of crop growth. However, at the later stages of crop growth, the nitrogen released from distillery effluents might supplement the nitrogen requirement of the crop. This further confirms that an integrated approach aims to use all the major sources of nutrients, so as to get maximum economic yield. When chemical fertilizer and distillery effluents are applied together, nutrients will be released first from the inorganic source and subsequently from the distillery effluent. Also, the nutrient losses will be minimized due to increased cation exchange capacity (CEC) with increased organic carbon content. Thus, the plant nutrients will be available as per the plants demand resulting in better growth, development and yield components.

In addition to the supply of nitrogen, distillery effluents (both solid and liquid) also supply other nutrients required by crop as these effluents contained other nutrients sufficiently (Table 3). These must have boosted the crop to yield better. The distillery effluent is known to contain a

considerable amount of plant nutrients (Pathak *et al.*, 1999). Bajpai and Dua (1972) suggested the use of distillery effluent as a nitrogen source by obtaining a significantly higher yield in sugarcane with 200 kg nitrogen through spent wash application. Further, Jadhav and Savant (1975) reported that distillery effluent can be profitably used as supplement to the fertilizer because of its higher manurial value. Kulkarni *et al.* (1987) classified spent wash as a liquid organic fertilizer with high nutrient contents and its nitrogen was mostly in colloidal form behaving as a slow release fertilizer better than most chemical fertilizers. Therefore, the yield potential in the present investigation was in agreement with findings of the above workers. The lower nutrient status in liquid effluent as compared to solid effluent and also higher nitrogen losses through leaching, volatilization and denitrification in liquid effluent might have resulted in poorer performance than solid effluent. Substitution of 25 to 50 per cent of nitrogen through solid and liquid effluents produced similar grain yield as obtained by 100 per cent substitution through inorganic source. Thus 25 to 50 per cent saving on cost of fertilizers could be achieved. Similar beneficial effect of distillery effluent on crop yield was also reported by Zalawadia and Raman (1994).

Grain yield is a function of yield contributing characters (Matsushima, 1976). Higher grain yield at S₅ was mainly influenced by yield components like cob length, cob girth, weight per cob, number of grains per cob, grain weight per cob and test weight (100-grain weight) as indicated by highly significant positive correlation (Appendix I) (Plate 1 to 4). Such improvements in yields were also observed by Bucknall *et al.* (1979) in barley, Vicente Chandler (1984) in rice, Perez Zamora *et al.* (1990) in sugarcane and Shankarappa (1993) in finger millet with the use of distillery wastes.



Plate 1. Cobs of rabi maize as influenced by 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic



Plate 3. Cobs of rabi maize as influenced by 100 per cent nitrogen through inorganic



Plate 2. Cobs of rabi maize as influenced by 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic



Plate 4. Cobs of rabi maize as influenced by 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent

Growth in plants has various phases which starts with an activation of embryo and ends with maturation of seed. The process involved in growth are very complex and vitally influenced by many factors of which nitrogen supply is one of the most important factors that determines the growth of crop. The differences in the yield components among the substitution levels were mainly due to the variations in growth parameters such as plant height, leaf area, leaf area index, leaf area duration and total dry matter production and its accumulation in different plant parts. The growth of the plant improved greatly particularly at S₅ in respect of plant height, leaf area, leaf area index, leaf area duration and total dry matter production and its accumulation in leaf, stem, cob and tassel at all the stages (Tables 4 to 12) which were comparable with that of S₇ and S₁₀ (Plate 5 to 8). The higher plant height at S₅, S₇ and S₁₀ at all the stages might be due to proper nourishment of crop. Shankarappa (1993) registered significantly higher plant height at 10,000 kg per ha distillery sludge along with recommended fertilizer dose in finger millet. Thus, it can be visualized that distillery effluents from the very beginning improved the overall growth from stage to stage when applied in combination with inorganic source. The number of leaves per plant did not vary significantly since it is determined by the genetic make up of the plant but leaf area per plant was markedly influenced by substitution levels.

The leaf area which indicates the photosynthetic assimilatory surface area of the plant depends largely on leaf mass. At all the stages of crop, leaf area per plant increased in S₅ (Table 6). However, it was statistically on par with other nitrogen substitution levels of S₇ and S₁₀. Whereas, significantly the lowest leaf area was recorded in S₉ but was



Plate 5. Growth of *rabi* maize as influenced by 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic



Plate 6. Growth of *rabi* maize as influenced by 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic



Plate 7. Growth of *rabi* maize as influenced by 100 per cent nitrogen through inorganic



Plate 8. Growth of *rabi* maize as influenced by 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent

found on par with other nitrogen substitution levels which substituted 100 per cent nitrogen through solid and liquid effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

There was a greater source sink relationship in S₅ and S₇ and S₁₀ which exhibited in the form of high leaf area index (Table 7) and number of grains per ear (Table 14). Higher photosynthetic surface and its persistence even at later stages of crop growth produced more assimilates at all the stages of crop growth. To retain most of the dry matter produced by photosynthesis, there should be a greater sink (grains/cob) which was very well developed by accumulating greater amount of photosynthates in crop established on S₅, S₇ and S₁₀. Thus, with the improvement in plant height, leaf area and leaf area duration resulted in higher total dry matter production in S₅. Total dry matter production improved considerably from 280.62 g per plant in S₉ to 331.57 g per plant in S₅.

The total dry matter production of crop during the growth period is important for the determination of the economic yield (Donald, 1962). Total dry matter production is a result of dry matter accumulation in individual plant parts. Higher total dry matter production in S₅, S₇ and S₁₀ as compared to other substitution levels (Table 9) was due to the fact that crop nitrogen requirement was fully met both at early and later stages. These three substitution levels also registered higher accumulation of dry matter in leaf, stem, cob and tassel growth. Similarly, increased dry matter and yield were also observed by Bucknall *et al.* (1979) in lowland grasses, Mbagwu and Ekwealor (1990) in maize, Jagadale and Sawant (1979) in sugarcane and Shankarappa (1993) in finger millet when they applied distillery effluents to these crops. The

lower dry matter accumulation in different parts in other nitrogen substitution levels which substituted 100 per cent through solid and liquid distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂) may be due to slow rate of decomposition and inadequate nitrogen availability during grand growth phase which was responsible for stunted growth with reduced dry matter production.

Due to higher accumulation of dry matter in plant, early initiation and greater development of reproductive system might be the possible consequences. Hence, tassels emerged early in S₅, S₇ and S₁₀ which facilitated the cobs to accumulate more photosynthates due to long duration available for photosynthates to accumulate resulting in higher yield and yield components (Table 13). Milthrape and Ivins (1966) reported that providing an additional nitrogen timely increased the total biomass. The results obtained in the present investigation are in accordance with the findings of Zalawadia and Raman (1994) that the total dry matter production recorded with full recommended dose of nitrogen, phosphorus and potassium and irrigated with tube well water was found on par with 75 per cent recommended dose of nitrogen, phosphorus and potassium along with spent wash.

Significantly the maximum stover yield (98.17 q per ha) recorded at S₅ was mainly due to the improved vegetative growth and the growth parameters such as total dry matter production and its accumulation in different plant parts like leaves and stem. However, stover yield at S₅ was found statistically on par with S₇ and S₁₀. A balance between the productive parts of the plant and the reserve which form an economic yield is essential. The harvest index followed the dynamics of corresponding grain and stover yield. The higher harvest index was

recorded in these three substitution levels (Table 15) indicating higher efficiency of translocation of photosynthates from source to sink.

5.2.2 Effect of nitrogen substitution with solid and liquid distillery effluent on quality parameters

The results on grain protein content revealed the beneficial effect of substitution levels of nitrogen through distillery effluents. Significantly higher and lower protein contents in grains were recorded in S₅ (11.14%) and S₉ (10.04%), respectively. Higher protein content could be due to more availability of nitrogen in soil (228.12 kg/ha) and further nitrogen content in grain (1.78%). Nitrogen is a major component of aminoacids. Concentration of nitrogen in both soil and plant was significantly lower in S₉ and hence recorded lowest protein content in grain. However, nitrogen substitution levels showed no significant effect on starch and reducing sugar content. Pujar (1995) reported that quality parameters in sugarcane were not influenced due to diluted effluent.

5.2.3 Effect of nitrogen substitution with solid and liquid distillery effluents on nutrient content in plant and total uptake

At anthesis, significantly higher nitrogen content was recorded in S₅ (3.17%) but was comparable with S₇ and S₁₀ due to increased availability of nitrogen in soil and higher uptake by crop. Whereas, phosphorus content at anthesis did not differ significantly. Nitrogen substitution levels significantly differed for potassium content at anthesis. Plants in 100 per cent substitution through solid and liquid effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂) showed higher concentration of potassium than substitution by combination of distillery effluents and inorganics or inorganics only due

to additional supply of potassium in soil by application of distillery effluents to substitute nitrogen. This was clearly confirmed by potassium content in soil after the harvest of crop. Salakinakop (1999) reported that nutrient concentration in wheat in sewage irrigated land was significantly higher than borewell irrigated land.

Nitrogen content in grain and stover and total uptake at harvest was significantly influenced by nitrogen substitution levels. Significantly higher nitrogen content in grain, stover and total uptake were recorded at S₅ but were comparable with other nitrogen substitution levels of S₇ and S₁₀ due to higher availability of nitrogen in soil (Table 24). Whereas, phosphorus, potassium, zinc, copper, iron and manganese contents in grain and stover did not get influenced significantly by substitution levels but their uptakes by crop showed significant response. Higher and lower uptake of nutrients were recorded in S₅ and S₉, respectively (Table 19 to 22). The results are in accordance with the study of Pandey *et al.* (1998) who indicated that nitrogen uptake of wheat was maximum with higher levels of nitrogen than lower levels because of higher availability in soil. Whereas, Pujar (1995) indicated significantly higher total uptake of nutrients in maize by irrigation of distillery effluent with river water.

5.2.4 Effect of nitrogen substitution with solid and liquid distillery effluents on soil property

Soil reaction, electrical conductivity, organic carbon and bulk density of soil were not influenced significantly by substitution of nitrogen with distillery effluents. This might be due to addition of distillery effluents to supplement only nitrogen requirement may be small enough to bring a significant change in physical and chemical properties of soil during the period of investigation.

The available nitrogen content in soil was significantly higher at S₉ due to lower uptake by the crop (Table 24). The available phosphorus content in soil was highest at S₂ substitution level due to additional supply of phosphorus from solid effluent and also due to lower uptake by the crop. The available potassium content differed significantly and highest content was recorded at 100 per cent nitrogen substitution through liquid effluent (S₁) which may be attributed to the application of distillery effluent to supplement the nitrogen, contained potassium sufficiently. Whereas, significantly lower potassium content in soil was recorded at S₁₀. This was in accordance with findings of Dongale and Savant (1978) who indicated an increased potassium content in soil when soil was treated with spent wash. Similarly, Perez Escobar and Ortiz Velez (1979), Vicente Chandler *et al.* (1984) and Shankarappa (1992) also reported increased potassium content of soil due to application of distillery wastes.

The available zinc, copper, iron and manganese in soil did not differ significantly due to nitrogen substitution levels but higher values were noticed at substitution levels which substituted 100 per cent nitrogen through solid and liquid distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂). Kulkarni (1987) stated that distillery effluents contained large amount of Ca, Mg, S as well as trace elements *viz.*, Cu, Mn and Zn. Whereas, Salakinkop (1999) reported that irrigation of sewage resulted in higher N, P, K, Zn, Cu, Fe and Mn in soil.

Highest gross returns were obtained in S₅ (Rs. 33,792/ha) which was closely followed by S₇ and S₁₀. However, the net returns of Rs. 21,457 per ha from the substitution level was almost identical with S₇ and S₁₀. Other nitrogen substitution levels of S₄ and S₆ were next in

order. The benefit:cost ratio was also maximum in all these substitution levels. The lowest net returns were obtained in S₉ (Rs.18,592/ha) and also benefit :cost ratio. Shankarappa (1992) recorded highest gross income, net returns and benefit cost ratio when 10,000 kg distillery sludge + $\frac{1}{2}$ recommended NPK with culture applied in ragi. The study indicated that there is a distinct possibility of safe disposal of distillery effluents by substituting them as a source of nitrogen and at the same time could save the cost on 50 per cent of recommended nitrogen fertilizer.

5.3 Experiment 2 : Studies on use of distillery effluent (Solid and Liquid effluents) as a source of nitrogen on the performance of wheat

5.3.1 Effect of nitrogen substitution with solid and liquid distillery effluents on growth and yield

Grain yield of wheat was significantly influenced by nitrogen substitution levels. Substitution of 50 per cent nitrogen through solid effluent plus 50 per cent nitrogen through inorganic source (S₅) resulted in significantly higher yield (53.14 q/ha) followed by nitrogen substitution levels of 25 per cent through solid effluent plus 75 per cent through inorganic source (S₇) (52.85 q/ha) and 100 per cent through inorganic source (S₁₀) (52.61 q/ha) and all these substitution levels were found on par among themselves (Table 33). Whereas, significantly lowest yield (45.01 q/ha) was recorded at 25 per cent substitution through solid effluent plus 75 per cent substitution through liquid effluent (S₉) and was found on par with nitrogen substitution levels of 100 per cent substitution through solid and liquid distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂). Grain yield at S₉ was accounted to 16.88 per cent lesser than S₁₀.

Results suggested that an integral of distillery effluents with inorganic source was better in harnessing higher grain yield. When these two applied together, nitrogen will be released first by inorganic source and subsequently from the distillery effluents. Thus, the plant nutrients will be available as per the plants demand resulting in better growth and development of crop. Distillery effluents supply other nutrients in addition to nitrogen when applied as a source of nitrogen and this also might be one of the reasons for higher yield at S₅ and S₇. Kulkarni (1987) stated that distillery effluent contained large amount of N, P, K, Ca, Mg, S as well as trace elements *viz.*, Cu, Mn and Fe. This was again in confirmation with composition of distillery effluents used in the present investigation (Table 3). Bajpai and Dua (1972) suggested the use of distillery effluent as a nitrogen source by obtaining a significantly higher yield in sugarcane with 200 kg nitrogen. Jadhav and Sawant (1975) reported that the manurial value of distillery effluent can be profitably used as supplement to the fertilizer. Patil (1998) reported that addition of fertilizer in combination with green leaf manure had beneficial effect in achieving higher productivity. Grain yield obtained at S₅ was found on par with S₇ and S₁₀. Thus, 25 to 50 per cent saving on cost of fertilizer could be achieved. Similar result was reported by Zalawadia and Raman (1994) in onion.

Yield is a complex terminal outcome of various phenomenal interaction among genotype, environment and management practices. In a given set of climatic conditions with similar management practices, different treatment combinations may lead to differences in grain yield because of external application of the fertilizers. The scenario with a combined application of distillery effluents and organics may lead to

favourable colloidal system which favours timely and adequate supply of nutrients. Eventually it was reflected on improved grain and straw yield in the present investigation. Though the application of distillery effluents to supplement 100 per cent nitrogen did indicate the increased availability of phosphorus and potassium (Table 42) that could not otherwise meet the crop demand to attain the targetted yield levels. Since wheat crop is nitropositive, respond for higher rates of nitrogen application.

Higher grain yield at S₅ was attributed to better expression of growth and yield components *viz.*, total dry matter production and its accumulation in leaf, stem and ear, number of productive tillers per metre row length, ear length, ear weight, number of grains per ear and test weight (1000-grain weight) as indicated by a highly positive correlation (Appendix II) (Plate 9 to 12). Similar results were obtained by Maurya and Verma (1990), wherein, higher rates of nitrogen application improved the yield attributes.

An increase in plant height was a general observation with increase in nitrogen fertilization (Tolessa, 1998). Cell enlargement and elongation are brought about due to availability of nitrogen through fertilization (Muthukrishnan and Subramanian, 1980). Perusal of results given in Table 27 indicated that height of plants was higher at S₅ followed S₇ and S₁₀ at all the stages of crop growth than other substitution levels (Plate 13 to 16). Providing additional nutrients particularly nitrogen was reported to increase the total biomass as shown by Milthrape and Ivins (1966).

Translocation of metabolites to the sink and maintenance of the proper source and sink relationship is an essential aspect of plant

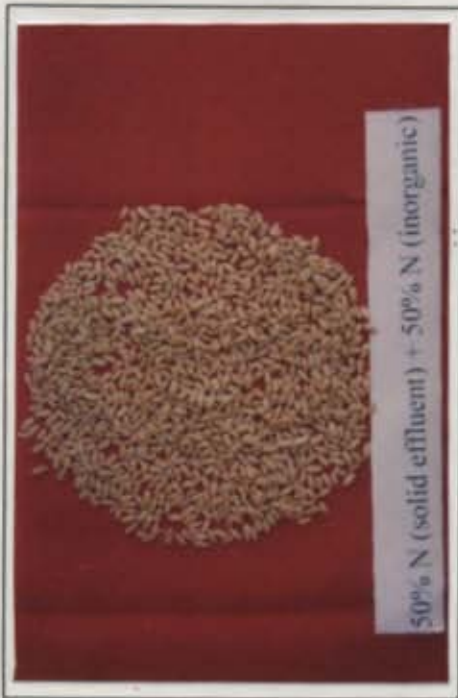


Plate 9. Grains of wheat as influenced by 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic

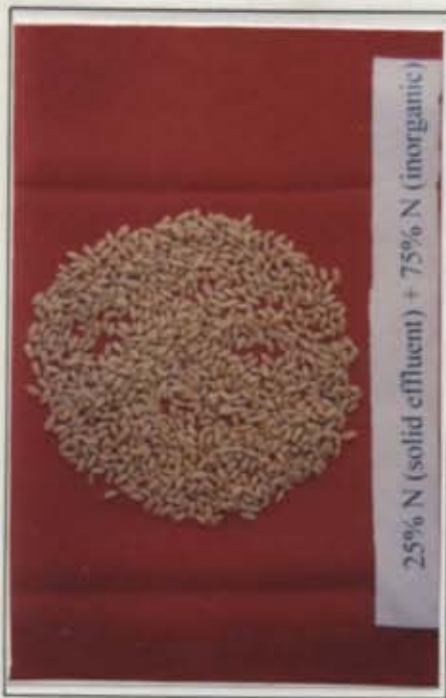


Plate 10. Grains of wheat as influenced by 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic



Plate 11. Grains of wheat as influenced by 100 per cent nitrogen through inorganic



Plate 12. Grains of wheat as influenced by 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through liquid effluent



Plate 13. Growth of wheat as influenced by 50 per cent nitrogen through solid effluent + 50 per cent nitrogen through inorganic



Plate 14. Growth of wheat as influenced by 25 per cent nitrogen through solid effluent + 75 per cent nitrogen through inorganic



Plate 15. Growth of wheat as influenced by 100 per cent nitrogen through inorganic



Plate 16. Growth of wheat as influenced by 100 per cent nitrogen substitution through liquid effluent

growth. Increase in leaf area index was noticed upto 60 days after sowing (DAS) and afterwards there was a decline in leaf area index. Higher leaf area index was noticed in these three substitution levels. This may be due to increased number of productive tillers and size of successive leaves. Nitrogen increases leaf area index or weight of leaf blades and this effect is greatest before panicle initiation in rice (Murata, 1966). The differences in leaf area index can also be attributed to the fact that nitrogen is the constituent of phosphonucleotides, which help for the increased cell division and expansion of cells resulting in higher leaf area index. The leaf area duration indicates the photosynthetic potential of crop. The leaf area duration was higher at S₅. The formation of optimum photosynthetic area and maintaining the leaves in photosynthetically active condition for longer duration during reproductive phase of the crop are considered essential for increasing the grain yield (Watson *et al.*, 1963).

The increased growth and high photosynthetic rate have a direct bearing on dry matter production. Grain yield and yield contributing characters are the reflections of dry matter accumulation in ear. At 90 days after sowing, significantly higher (95.25 g/ear) and lower (80.85 g/ear) dry matter accumulation in ear were noticed at S₇ and S₉, respectively. The lower dry matter accumulation in ear was due to lower photosynthetic ability of the plant as noted by lower dry matter accumulation in leaf and lower translocation of metabolites from leaf and stem during reproductive phase of crop growth. The superiority of S₅ for total dry matter production per metre row length (Table 29) clearly established the fact that the availability of nitrogen and other nutrients was higher with the external application of solid effluent to substitute

nitrogen. This substitution level required more number of days (56.40) than other substitution levels resulted in higher vegetative growth thereby postponing heading period to build a proper structure for higher dry matter production, leaf area index and yield.

Thus, it can be visualized that combination of distillery effluents with inorganic source from very beginning improved the overall growth. This was in accordance with result of Shankarappa (1993) in finger millet by application of distillery sludge. Such improvements in yield were also reported by Bucknall *et al.* (1979) in barley, Vincente Chander (1984) in rice and Perez Zamora *et al.* (1990) in sugarcane with the use of distillery effluent.

Straw yield in wheat was significantly higher at S5 (68.13 q/ha). Needless to emphasize that straw yield is more a function of plant height, number of tillers and dry matter accumulation in leaf and stem. This indicated that increased native nitrogen status of the soil and its availability in right times. Other nitrogen substitution levels which substituted 100 per cent nitrogen through solid and liquid effluents either in combination or individually could not meet the nitrogen demand timely and adequately which was clearly reflected on straw yield. Higher harvest index was again noticed at S5 (Table 33) indicating higher efficiency of translocation of photosynthates from source to sink which ultimately increased the grain yield. Whereas, S9 recorded significantly lower harvest index than other substitution levels.

5.3.2 Effect of nitrogen substitution with solid and liquid distillery effluents on quality parameters

Grain quality was assessed to determine protein, sedimentation value, dry gluten and wet gluten content. Quality of wheat depends on

complex number of factors relating to how it grows, mills and adopts an end use in any of the different kinds of products. Grain protein content, probably the most important single factor in bread making quality, is largely determined by growth environment. Substitution level of S₅ produced grains with maximum protein content (12.56%) compared to other nitrogen substitution levels. Whereas significantly the lowest protein content was recorded at S₉ (10.98%). The higher protein content at S₅ could be due to higher availability of nutrients especially nitrogen in soil (224.83 kg/ha) and further nitrogen content in grain (2.01%).

The complex composition of wheat protein is partly due to the polyploid genetic constitution. Bread wheat is hexaploid and has 21 chromosome pairs and quality composition of protein is less affected by growth environment. When wheat flour is mixed with water and sufficiently blended, a gluten matrix will form. Grains obtained from S₅ produced the maximum sedimentation value, dry gluten and wet gluten (Table 34) as a result of high content of protein in grains. Biradar (1997) reported that grain protein content in wheat showed higher response to higher level of nitrogen application. Salakinkop (1999) reported that quality of wheat when grown on sewage irrigated land was improved over borewell irrigated land.

5.3.3 Effect of nitrogen substitution with solid and liquid distillery effluents on nutrient contents in plant and total uptake

Significantly higher nitrogen content in plant at anthesis was recorded at S₅ but was comparable to nitrogen content at S₇ and S₁₀ (Table 34). The higher nitrogen concentration in leaves help the crop to retain leaves for longer time and this might have increased photosynthesis, number of grains per ear and higher grain weight.

Whereas, phosphorus content was not influenced significantly by nitrogen substitution levels. Potassium contents in plants were significantly higher at nitrogen substitution levels which substituted 100 per cent through solid and liquid distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂) due to additional supply of potassium to soil by application of distillery effluents to substitute nitrogen. At harvest, nitrogen content in grain, straw and total uptake were maximum at S₅ followed by S₇ and S₁₀ (Table 36). Halepyati (1989) obtained higher uptake of nitrogen when green manure was applied in combination with inorganic nitrogen source. Phosphorus, potassium, zinc, copper, iron and manganese contents in grain and straw did not differ significantly by substitution levels however their total uptakes were influenced significantly. Uptake of nutrients by wheat was maximum at S₅ (145.37, 43.84, 95.50, 0.296, 0.248, 2.46, 0.986 kg/ha) followed by S₇ (144.07, 43.47, 95.21, 0.295, 0.247, 2.46 and 0.979 kg/ha) and S₁₀ (142.51, 43.18, 92.20, 0.289, 0.243, 2.44 and 0.962 kg/ha nitrogen, phosphorus, potassium, zinc, copper, iron and manganese, respectively) over other substitution levels. Similarly, increased uptake of many essential nutrients by ragi was also noticed by Shailendranath and Rao (1979) when they pre-treated urea and rock phosphate fertilizers with brewery effluent. However, Vincente Chandler *et al.* (1984) reported that the leaf contents of N, P, K, Ca and Mg of rice were not affected by levels of distillery effluent. Pujar (1995) obtained higher value of Zn, Cu, Fe and Mn uptakes at lower dilution levels of distillery effluents than higher dilution levels in wheat.

5.3.4 Effect of nitrogen substitution with solid and liquid distillery effluents on soil properties

Though soil reaction, electrical conductivity, organic carbon and bulk density of soil were not influenced significantly by nitrogen substitution levels, their values increased at substitution levels which

substituted 100 per cent nitrogen through solid and liquid effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂). The soil reaction, electrical conductivity, organic carbon and bulk density were ranged from 7.10 to 7.17, 0.47 to 0.63 dSm⁻¹, 0.47 to 0.51 per cent and 1.49 to 1.52 Mg per m³, respectively. Similar results have been reported by Shankarappa (1992).

The available nitrogen content of soil (Table 42) indicated that in nitrogen substitution level of S₅, higher uptake by the crop resulted in lower available nitrogen content in soil. While, in substitution levels of S₉, S₁, S₈ and S₂, lower uptake by crop resulted more available nitrogen content in soil. The superior performance of the combined application of distillery effluents and inorganic source may be attributed not only to the supply of nitrogen by the distillery effluents but also supply of other nutrients in soil besides its influence on the chemical and biological processes of soil. The higher phosphorus and potassium contents in soil at substitution levels which substituted 100 per cent nitrogen through distillery effluents were due to increased quantity of distillery effluents added to substitute required nitrogen also contained phosphorus and potassium sufficiently. Chatterjee *et al.* (1979) noticed increased phosphorus and potassium when spent crop (waste from brewery factory) was applied to soil at the rate of 10 t per ha. Increased pH and K contents were also observed by Sweeny and Graetz (1988) with application of anaerobically digested molase residue effluent to soil. Though the available zinc, copper, iron and manganese contents in soil were not influenced significantly by nitrogen substitution levels, higher values were seen at 100 per cent substitution through distillery effluents either in combination (S₃, S₃ and S₉) or individually (S₁ and S₂). Salakinkop (1999) reported that irrigation of sewage resulted in higher N, P, K, Zn, Cu, Fe and Mn in soil.

The nitrogen substitution level of S₅ recorded the highest gross income (Rs.46,660/ha) which was almost identical with S₇ and S₁₀. The net returns also were highest in these substitution levels. Shankarappa (1992) recorded highest gross income, net returns and benefit cost ratio when 10,000 kg distillery sludge + ½ recommended NPK with culture applied in ragi. Premsekhar *et al.* (1997) reported higher net returns and benefit cost ratio due to combined use of FYM or green manure with 75 per cent of the inorganics. The highest benefit:cost ratio of 2.95 was obtained with S₅ and S₁₀ which was closely followed by S₇. From this study, it indicate that nitrogen substitution from 25 to 50 per cent through distillery effluents resulted almost same gross income, net returns and benefit :cost ratio as obtained with S₁₀ thus saving the cost on 50 per cent of nitrogen fertilizer.

5.4 Experiment 3 : Studies on the performance of *rabi* maize against graded dilution of liquid distillery effluent as a source of irrigation

5.4.1 Effect of dilution levels on growth and yield

A significant difference was noticed among the dilutions with respect to grain yield. The grain yield of maize in plots irrigated with good water was 66.97 q per ha which increased significantly to 76.82 q per ha at dilution level of 1:5 recording an increase of 14.72 per cent over former. It is well established fact that irrigation meets the water requirement of crop but effluent irrigations meet both water and nutrient requirement. Maize is a heavy feeder and took up more nutrients from 1:5 dilution level. Higher concentration of nutrients in lower dilution of effluent had supplied more nutrients to the maize. Irrigation by lower dilution levels to soil have increased the availability of nutrients in soil and their uptake by crop thus resulting in higher growth and yield of

maize. However, grain yield of maize showed significant response upto 1:10 dilution level (75.01 q/ha) but there was a progressive response at 1:5 dilution level. The results are in agreement with findings of Zalawadia *et al.* (1997) that less diluted spent wash gave a greater yield of biomass than more diluted ones. Singh and Raj Bahadur (1997) stated that maize crop withstood irrigation with 5 times diluted effluent and Pujar (1995) recorded higher grain yield in maize at 10 times dilution of effluent.

Irrigation by undiluted effluent resulted in drastic reduction in grain yield (24.06 q/ha) which accounted to 178.34 per cent lesser than irrigation by only good water. The drastic reduction was in confirmation with the studies of Totawat (1991) that the growth and dry matter production of maize, sorghum and barley significantly decreased when undiluted effluent was used for irrigation. However, effluent when diluted with borewell water and used for irrigation had improved the growth and yield parameters. The reduction in grain yield might be due to the toxic effects from excessive quantities of soluble salts and solid materials in the effluent and addition of soluble salts and solid materials might have affected soil porosity due to undiluted effluent irrigation which resulted in reduced germination of the seed, reduced uptake of the nutrient and ultimately affected growth and yield as evident from the tables. Irrigation by 1:5 dilution level to soil increased the availability of nutrients in the soil (Table 65 and 66) and their uptake (Table 59 to 63) and thus resulted in higher growth (plant height, leaf area, leaf area index, leaf area duration, total dry matter production and its accumulation in different parts) and yield components (cob length, cob girth, weight/cob, number of grains/cob, grain weight/cob and test weight) and consequently the grain yield of maize.

Data on growth and yield attributes such as plant height, leaf area, leaf area index, leaf area duration, total dry matter production and its accumulation in leaf, stem, and tassel, cob length, girth, weight per cob, number of grains per cob, grain weight per cob, test weight revealed that they were significantly higher at lower dilution level of 1:5 which found superior over rest of dilution levels except 1:10 (Plate 17 to 24). Irrigation by 1:5 dilution level resulted in significantly taller plants at all the stages of crop growth. The number of leaves per plant did not vary significantly, since it was determined by the genetic make-up of the plant but leaf area per plant was significantly higher (Table 47) and it was due to improvement in leaf growth and development. These findings are in agreement with findings of Singh and Raj Bahadur (1997). The decrease in leaf area with advance in age of crop may be related to the senescence of the older leaves and reduction in chlorophyll. Higher leaf area index at 1:5 dilution level ultimately increased the leaf area duration (Table 49).

Maize is one of the first species shown to use the C₄ photosynthetic pathway. The dry matter production increased as dilution levels decreased upto 1:5. In the early growth stages, maximum dry matter was found in stem and leaf while in the later stages it was maximum in cobs. Hanway (1962) reported a similar dry matter accumulation pattern in maize under field conditions. From grain filling stage onwards, dry matter accumulation in cob increased and this may be due to improved sink capacity which received the metabolites translocated from other plant parts. There was higher dry matter production due to higher leaf area and plant height. Positive correlation between yield and plant height ($r^2 = 0.978$), leaf area ($r^2 = 0.961$) and dry matter production ($r^2 = 0.997$) at harvest were observed. The response was seen at a lower level of dilution



Plate 17. Growth of rabi maize as influenced by dilution level of 1:5 (liquid effluent : good water)



Plate 18. Growth of rabi maize as influenced by dilution level of 1:10 (liquid effluent : good water)



Plate 19. Growth of rabi maize as influenced by irrigation with good water



Plate 20. Growth of rabi maize as influenced by irrigation with undiluted effluent



Plate 21. Cobs of *rabi* maize as influenced by dilution level of 1:5 (liquid effluent : good water)



Plate 22. Cobs of *rabi* maize as influenced by dilution level of 1:10 (liquid effluent : good water)



Plate 23. Cobs of *rabi* maize as influenced by irrigation with good water



Plate 24. Cobs of *rabi* maize as influenced by irrigation with undiluted effluent

as compared to higher level of dilutions for most of the growth attributes, thus corroborating with yield attributes and grain yield.

The maximum total dry matter production of 355.99 g per plant at harvest was registered at 1:5 dilution level as against 302.97 and 152.93 g per plant at irrigation by good water and undiluted effluent, respectively. The increase in this character resulted in the development of efficient photosynthetic system, which might have enabled the plant to intercept higher amount of radiant energy and converted the same into chemical energy. Due to higher accumulation of dry matter per plant, early initiation and greater development of reproductive system might be the possible consequences. Tassels emerged early in 1:5 dilution level (Table 54) compared to other dilution levels. Early tasseling facilitated the cobs to accumulate more photosynthates due to longer duration available for photosynthates to accumulate and hence higher yield components and yield.

Stover yield depends on the development of culm, leaf dry matter, partitioning between vegetative and reproductive sinks and rate of dry matter accumulation. A significantly higher stover yield of 106.77 q per ha was recorded in lower dilution level of 1:5 followed by 1:10 dilution level (104.75 q/ha). The results are in accordance with the findings of Totawat (1991) that when zinc smelter effluent was diluted with water and used for irrigation resulted in increased dry matter yield of maize, sorghum and barley. Escolar (1966) observed increased yield in snapboan due to application of spent wash. Significantly the lowest stover yield (36.87 q/ha) was recorded in irrigation by undiluted distillery effluent. Sahai *et al.* (1983) revealed that the distillery effluent contained an excess of various forms of cations and anions which are injurious to

plant growth. The concentration of these constituents should be reduced to beneficial level by diluting the effluent and can be used for irrigation purpose.

Harvest index is the result of better translocation of photosynthates from source to sink which ultimately increase the grain yield. Significantly higher harvest index (0.418) was recorded at lower dilution level of 1:5 as compared to other dilution levels (Table 56). The better performance of crops in lower dilution level was attributed to its manurial effect at lower dilution levels. Use of effluent at lower dilution levels must have supplied more nutrients as compared to higher ones. This was further confirmed by nutrient content in soil after harvest (Table 65 and 66) and their uptake (Table 59 to 63). Dongale and Savant (1978) reported that spent wash was as good as KCl, a source of potassium for jowar. Chares (1985) stated that distillery effluent was used as a complement to mineral fertilizer to sugarcane in Brazil. Further, Crowford (1985) reported an increase in the yield of maize (85 to 105 q/ha) and peanuts (15.5 to 20.0 q/ha) with municipal waste water.

5.4.2 Effect of dilutions levels on quality parameters

Decrease in dilution levels increased the protein and reducing sugar percentage in grains reaching highest at irrigation by undiluted effluent. In lower dilution levels, increased uptake supplied through effluent irrigation resulted sufficiently higher concentration of nitrogen in grains resulting higher protein content. In irrigation by undiluted effluent plots, significantly lesser grain yield produced resulted in more nitrogen accumulation and eventually more protein distribution. Protein content showed an increased trend at lower dilution of effluent irrigation (Pujar, 1995). However, dilution levels showed no significant influence on starch content in grains.

5.4.3 Effect of dilution levels on nutrient contents in plant and their total uptake

Nitrogen, phosphorus and potassium contents in plant at anthesis were significantly on higher side at lower dilution levels than higher dilution levels due to increased availability of nutrients in soil by application of higher concentration of effluents at lower effluent dilution levels. Nitrogen and potassium contents in grain and stover were influenced significantly by dilution levels by recording higher values at lower dilution levels however phosphorus content was numerically on higher side at lower dilution levels though did not differ significantly. The total uptake of nitrogen, phosphorus and potassium by plant showed significant variation due to dilution levels recording significantly higher uptake at lower dilution level of 1:5 (195.45, 43.26 and 173.79 kg/ha, respectively) which was found on par with next dilution level of 1:10. This could be attributed to the higher nutrient supply at the lower dilution of effluent. However, further dilution of 1:25, 1:50 and irrigation by good water must have supplied lesser amounts of nutrients when compared to lower dilution levels resulting lesser uptake by the crop.

Despite the fact that zinc, copper, iron and manganese contents in grain and stover did not differ significantly among different dilution levels, numerically higher values were recorded at lower dilution levels as the effluent contained appreciable quantity of these micronutrients (Table 3). However, total uptake of Zn, Cu, Fe and Mn showed significant variation at different dilution levels (Table 62 and 63). The total uptake showed an increasing trend at lower dilution levels. Whereas, irrigation by undiluted effluent recorded the lowest uptake of nutrients due to severe reduction in growth and development of crop though the soil was sufficiently high in nutrient contents.

5.4.4 Effect of dilution levels on soil properties

A good state of soil physical environment is important for maintaining sustained productivity. A concept embodied in the presumption is that good soil tilth is the precursor to high productivity. While, with increase in effluent proportions there was decrease in bulk density and the lowest bulk density of 1.39 Mg per m³ was recorded at undiluted effluent irrigation. This may be due to higher organic carbon content in the soil through the addition of effluent.

In sandy loam soil which has very high rate of infiltration, reduction in bulk density would be advantageous as it would help to store more water in surface soil for longer time. Similar results have been reported by Singh and Raj Bahadur (1997 and 1998) and further Singh *et al.* (1995) reported the beneficial effect of effluent application on soil properties *viz.*, bulk density and infiltration rate.

The results showed a gradual increase in pH values of soil due to addition of effluent. The electrical conductivity of soil was significantly higher in plots irrigated with undiluted effluent which was due to higher electrical conductivity of effluent added (20.8 dSm⁻¹). There was much improvement in soil organic carbon with lesser dilution levels (Table 64). The results are in confirmation with those reported by Sweeny and Graetz (1991) who observed that addition of distillery effluent, regardless of rate raised the soil pH owing to increase in soil K, Ca, Mg and Na levels. The significant increase in the organic carbon content of the soil with effluent irrigations could be attributed to the fact that the effluent contains high organic load. The available nitrogen, phosphorus, potassium, zinc, copper, iron and manganese contents of the soils were

also significantly influenced with effluent irrigation. The contents of all these increased with an increase in the quantity of effluent added confirming the fact that the effluent contained all these nutrients in sufficient amount. There were supported by findings of Taluk and Medeirious (1989), Shinde *et al.* (1993), Zalawadia and Raman (1994) and Singh and Raj Bahadur (1998).

Lower dilution level of 1:5 recorded the highest gross income (Rs.36,976/ha) which was closely followed by 1:10. These two dilution levels again recorded higher net returns and benefit cost ratio. Whereas, irrigation by undiluted effluent recorded the lowest gross return, net return and benefit:cost ratio. Thus, liquid distillery effluent can be successfully used as a source of irrigation with good water upto the dilution level of 1:5.

5.5 Experiment 4 : Studies on the performance of wheat against graded dilution of liquid distillery effluent as a source of irrigation

5.5.1 Effect of dilution levels on growth and yield

Grain yield of wheat differed significantly due to different dilution levels. Significantly higher grain yield (52.59 q/ha) was obtained at higher dilution level of 1:50 but was found statistically on par with irrigation by good water (51.29 q/ha). Whereas, lower dilution levels which received higher concentration of effluent registered significantly lesser yield. The per cent reduction in grain yield was to an extent of 7.75 in 1:25, 3.19 in 1:10 and 21.37 in 1:5 dilution levels over irrigation by good water. Reduction in yield due to irrigation with paper factory effluent as compared to river water was reported by Malleshappa (1979)

in soybean and Sheshadri (1980) in finger millet. The results were also in accordance with findings of Pujar (1995).

There was a significant reduction in grain yield when undiluted effluent was used for irrigation and the reduction accounted to 385.70 per cent over irrigation by good water. This might be due to higher concentration of the effluent which contained an excess of various cations and anions and these act as retardants to plant growth since they have been reported to affect the water absorption and other metabolic processes of the plants. Similar results have been obtained by earlier workers (Rajanan and Oblisamy, 1979; Khosla, 1980). Devarajan and Oblisamy (1995) reported that undiluted effluent was not suitable whereas the 50 times diluted effluent was found to be suitable for rice crop. Higher BOD and COD might have an adverse effect on crop growth which resulted in higher respiration causing deplasmolysis of the plant.

The higher grain yield at higher dilution level was influenced by yield attributing characters, *viz.*, ear length, ear weight, number of grains per ear and test weight (1000-grain weight) as indicated by highly significant positive correlation (Appendix IV). The higher grain yield at higher dilution was also influenced by better expression of growth and yield components like total dry matter production and its accumulation in different parts, number of productive tillers, leaf area index, leaf area duration, ear length, ear weight, number of grains per ear and test weight. The test weight in plots irrigated with dilution level of 1:50 was 40.98 which decreased significantly with decrease in dilution levels. Whereas, test weight in case of undiluted effluent was only 14.29 g because of more chaffy and unfilled nature of grains (Plate 25 to 28). It may be noted that application of excessive nutrients particularly nitrogen



Plate 25. Grains of wheat as influenced by dilution level of 1:50 (liquid effluent : good water)



Plate 26. Grains of wheat as influenced by irrigation with good water



Plate 27. Grains of wheat as influenced by dilution level of 1:5 (liquid effluent : good water)



Plate 28. Grains of wheat as influenced by irrigation with good water

increases the sterility and eventually more unfilled grains (Anon, 1971). Similar observations were also made by Nagaraj (1981) and Pujar (1995).

Perusal of results presented in Table 68 indicated that height of plants was significantly higher at 1:5 dilution level and increase in height over good water irrigated plot was 17.98 per cent. It might be due to availability and uptake of more nutrients (Table 83, 84, 77, 78, 79, 80 and 81), enhancing the vegetative growth (Plate 29 to 32). It may be recalled here that the distillery effluent contained (Table 3) fairly higher quantity of major and micronutrients. It is well established fact that under nutrient rich soil, plants grow vertically and slender.

There was a greater source, sink relationship in 1:50 dilution level which exhibited in the form of higher leaf area index and number of grains per ear. Greater photosynthetic surface and its persistence even at later stage of crop produced more assimilates at all the stages of crop growth. To retain most of the dry matter produced by photosynthates, there should be a greater sink. The sink (grains/ear) was very well formed (43.70 grains/ear) and developed by accumulating greater amount of photosynthates in crop established on higher dilution level of 1:50. The better performance of crop in higher dilution level was also due to moderate plant height and more number of productive tillers.

The total dry matter accumulation was maximum in higher dilution level of 1:50 (213.11 g/m row length) and decreased significantly with decrease in dilution levels. The increase in total dry matter production may be due to higher leaf, stem and ear dry matter accumulation in 1:50 dilution level which also resulted in delayed heading (Table 73) which provided longer period for photosynthesis to accumulate. The dilution



Plate 29. Growth of wheat as influenced by dilution level of 1:50 (liquid effluent : good water)



Plate 31. Growth of wheat as influenced by dilution level of 1:5 (liquid effluent : good water)



Plate 30. Growth of wheat as influenced by irrigation with good water



Plate 32. Growth of wheat as influenced by irrigation with undiluted effluent

level which received 1:50 had favoured significantly higher number of productive tillers over lower dilution levels (Table 70). This resulted in 25.54, 17.73 and 11.14 per cent increase over 1:5, 1:10 and 1:25 dilution levels. Similar results have been reported by Pujar (1995).

Straw yield in wheat was significantly higher in plots irrigated with 1:50 dilution level (67.23 q/ha). The straw yield showed a decreased trend at lower dilution levels. The higher straw yield observed at 1:50 dilution level could be attributed to significant increase in total dry matter production and its accumulation in leaves and stem and also due to increased uptake of nutrients from soil. Providing additional nitrogen was reported to increase the total biomass as reported earlier by Milthrape and Ivins (1966). Similarly, Syev *et al.* (1964) observed increased fodder yield of maize by 40 per cent due to sewage irrigation as compared to stream water. The results were also in confirmation with findings of Day and Tucker (1959). Harvest index was significantly higher at higher dilution level of 1:50 confirming that there was better translocation of photosynthates from source to sink which ultimately resulted in higher grain yield in plots irrigated with 1:50 dilution.

5.5.2 Effect of dilution levels on quality parameters

The protein content in wheat grains was the highest in plots irrigated with undiluted effluent which was found on par with lower dilution levels. The increased protein content in these dilution levels might be due to higher content of nitrogen in grains (2.12%) and significantly lower grain yield produced resulting in more nitrogen accumulation and eventually more protein distribution. The results thus obtained, lend support of the findings of Day and Tucker (1959) that

crude protein content in seeds showed an increase with treated municipal waste water (sewage) application. The other quality parameters such as sedimentation value, wet gluten and dry gluten were also influenced as a result of higher grain protein content. The results obtained here confirms the findings of Salakinkop (1999) that quality parameters of wheat were improved under sewage irrigation. However, Mohan Singh *et al.* (1993) observed juice quality parameters such as pol per cent and purity coefficient remained unaffected on addition of 500 m³ distillery effluent.

5.5.3 Effect of dilution levels on nutrient contents in plant and total uptake

The dilution levels showed significant effect on contents of nitrogen, phosphorus and potassium at anthesis (Table 76). The contents were significantly higher at lower dilution levels due to increased availability of nutrients in soil attributed to higher content and uptake by plants. Whereas, at harvest nitrogen and potassium contents in grain and straw were influenced significantly by dilution levels. Though the phosphorus content was found nonsignificant, higher values were noticed at lower dilution levels. The total uptake of nitrogen, phosphorus and potassium showed a significant response to dilution levels by recording higher total uptake at higher dilution levels (Table 83 and 84).

Micronutrients such as Zn, Cu, Fe and Mn contents in grain and straw showed nonsignificant response however higher values were noticed at lower dilution levels confirming effluent used was fairly higher in these nutrients (Table 3). However, total uptake of zinc, copper, iron and manganese were significantly higher at higher dilution levels than

higher ones. Whereas, significantly lowest uptake was recorded in plots irrigated by undiluted effluent followed by irrigation with good water as severe reduction in total biomass and no additional nutrient application through effluent, respectively.

5.5.4 Effect of effluent dilution on soil properties

There was a significant influence on physical property (Table 82). Bulk density decreased significantly at lower dilution levels. There was a gradual increase in soil pH with decrease in dilution levels which was due to higher pH and K, Ca, Mg and Na content of the effluent (Table 3). Soils irrigated with different dilution levels indicated that electrical conductivity of soil increased significantly with lower dilution levels. This was attributed to higher electrical conductivity of effluent (20.8 dSm^{-1}) which contained higher electrolyte concentration. The present findings are in agreement with findings of Jadhav and Savant (1975) and Shinde *et al.* (1993). Irrigating the soil with different dilutions indicated that organic carbon status of soils increased significantly with increase in concentration of effluent.

The available nitrogen, phosphorus, potassium, zinc, copper, iron and manganese contents in soil were significantly higher at lower dilution levels (Table 83 and 84). This was due to increased quantity of effluent added in the form of irrigation and mineralization induced through microorganisms. Similar results have been reported by earlier workers (Schirado *et al.*, 1986; Grigoryan, 1990; Totawat, 1991; Pawar *et al.*, 1992 and Shinde *et al.*, 1993).

Higher dilution level of 1:50 obtained the maximum gross return (Rs.46,106/ha) and was closely followed by irrigation with good water

(Rs. 44,982/ha). Further, net return was highest in 1:50 dilution level and was closely followed by irrigation by good water. The benefit:cost ratio was also higher in 1:50 dilution level. Thus, the study indicates that the higher dilution level of 1:50 was found economically good for wheat crop.

Practical utility of experiments

1. Better plant growth, yield and quality parameters of maize and wheat were recorded at nitrogen substitution level of 50 per cent through solid effluent plus 50 per cent through inorganic source indicated the possibility of substitution of inorganic nitrogen upto 50 per cent.
2. Though the 100 per cent nitrogen substitution through distillery effluents improved the nutrient status of soil, but these substitution levels could not meet the nitrogen requirement by the crop timely and adequately.
3. Among the dilution levels tested, lower dilution level of 1:5 found better for maize crop in terms of productivity and quality while for wheat crop 1:50 dilution found better.
4. Soil fertility status was substantially increased at lower dilution levels.

Future line of work

1. Different crops respond differently to dilution levels of liquid distillery effluent with water. Hence, screening of major crops for their suitability to distillery effluent as an irrigation water on growth and yield would be useful.

2. Long term experiments need to be conducted on diverse crops and soil types so as to ascertain the benefits of distillery effluents for improving the yield and quality of crop and also physical, chemical and biological properties of soil.
3. The releasing pattern of nutrients from distillery effluents could be studied to optimize its time and quantity of application to different crops.
4. Apart from containing substantial amount of nitrogen, both solid and liquid effluents contained good amount of potassium and other nutrients. Hence, it may be tried as a complete manure to field crops.

Summary

VI. SUMMARY

Field experiments were conducted to study "Agronomic investigation on use of distillery effluents on the performance of *rabi* maize and wheat" during two consecutive *rabi* seasons of 1999-2000 and 2000-2001 on farmers field near Sri Lakshmi Narayana Distillery unit, Garag. There were four field experiments. First and second experiments consisted of ten nitrogen substitution levels with three replications. Whereas, third and fourth experiments consisted of six dilution levels with four replications. All experiments were laid out in a randomised complete block design. The experimental results were summarised below.

Grain yield at substitution level of 50 per cent through solid effluent plus 50 per cent through inorganic source (S₅) was significantly higher (70.17 q/ha) and was found on par with substitution levels of 25 per cent through solid effluent plus 75 per cent through inorganic source (S₇) and 100 per cent substitution through inorganic source (S₁₀). Further, grain yield at S₁₀ (69.40 q/ha) was found on par with substitution levels of 25 per cent through liquid effluent plus 75 per cent substitution through inorganic source (S₆) and 50 per cent substitution through liquid effluent plus 50 per cent substitution through inorganic source (S₄).

Grain yield at S₅ was mainly influenced by higher yield parameters such as cob length, cob girth, weight per cob, number of grain per cob, grain weight per cob and test weight.

The differences in yield parameters among nitrogen substitution levels were mainly due to variation in growth parameters such as plant height, leaf area, leaf area index, leaf area duration, total dry matter

production and its accumulation in different parts. All these growth parameters found higher at S₅, but was comparable with 100 per cent substitution through inorganic source. However, all growth and yield parameters found lower at 25 per cent substitution through solid effluent plus 75 per cent substitution through inorganic source (S₉) resulting significantly lesser yield but was comparable with other nitrogen substitution levels which substituted 100 per cent nitrogen through distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

Significantly highest stover yield at S₅ was recorded (98.47 q per ha) which was found on par with S₇ and S₁₀. Further, stover yields of S₁₀, S₆ and S₄ were found on par among themselves. Substitution level of S₅ also recorded higher harvest index. Lesser days for 50 per cent tasseling was taken by S₅ than other substitution levels followed by S₇ and S₁₀.

Higher content of nitrogen at anthesis in plant was recorded again at S₅. Substitution levels improved protein content at S₅ than other substitution levels however reducing sugar and starch contents were not influenced significantly. Whereas, phosphorus content showed nonsignificant response. However, potassium content at anthesis varied significantly and higher values were recorded at all the substitution levels which substituted 100 per cent through distillery effluent either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

At harvest, nitrogen contents in grain and stover were higher at S₅. Whereas, phosphorus, potassium, zinc, copper, iron and manganese contents did not influenced significantly by nitrogen substitution levels but the total uptake of all these nutrients showed significant response.

Substitution level of 50 per cent through solid effluent plus 50 per cent through inorganic source (S₅) recorded higher total uptake of these nutrients compared to other substitution levels.

Nitrogen substitution levels did not influence soil reaction, organic carbon and bulk density of soil significantly but it influenced electrical conductivity, available nitrogen, phosphorus and potassium considerably. However, zinc, copper, iron and manganese contents were not influenced significantly. Thus, performance of crop in the form of yield and quality were improved in combination of distillery effluent with inorganic source.

Gross return and net returns were maximum with S₅ (Rs.33,792 and Rs.21,457/ha, respectively) and was closely followed by S₇ and S₁₀. Whereas, nitrogen substitution level of S₉ recorded the lowest gross return and net returns. B:C ratio was highest with S₅ (1.74) and was very closely followed by S₁₀ (1.73).

Significantly higher grain yield of wheat was recorded at 50 per cent substitution through solid effluent plus 50 per cent substitution through inorganic source (S₅) (53.14 q/ha) but was found on par with nitrogen substitution levels of 25 per cent through solid effluent plus 75 per cent through inorganic source (S₇) and 100 per cent substitution through inorganic sources (S₁₀).

Growth and yield parameters such as plant height, leaf area index, leaf area duration, number of productive tillers, total dry matter production and its accumulation in different parts, days to 50 per cent heading, ear length, ear weight, number of grains per ear and test weight were higher at S₅. Whereas, lower values of all growth and yield

parameters at 25 percent substitution through solid effluent plus 75 per cent substitution through inorganic sources (S₉) resulted in significantly lower yield (45.01).

Straw yield of wheat was significantly higher at S₅ (68.13 q/ha) but was found on par with S₁ and S₁₀. Harvest index also followed the same trend.

Protein, sedimentation value, wet gluten and dry gluten values were considerably higher at S₅. Significantly higher nitrogen content in plant at anthesis was also recorded at S₅. Whereas phosphorus and potassium contents were higher at plants on other nitrogen substitution levels which substituted 100 per cent through distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂).

At harvest, nitrogen content in grain and stover were found higher at S₅. Whereas, other nutrients such as phosphorus, potassium, zinc, copper, iron and manganese contents were not differed significantly due to nitrogen substitution levels. The total uptake of all there nutrients were higher at nitrogen substitution level of 50 per cent through solid effluent plus 50 per cent through inorganic source (S₅).

Soil reaction, organic carbon and bulk density were not influenced significantly by nitrogen substitution levels, however, electrical conductivity, available nitrogen, phosphorus and potassium contents were influenced significantly. Available phosphorus and potassium contents were higher at substitution levels which substituted 100 per cent nitrogen through distillery effluents either in combination (S₃, S₈ and S₉) or individually (S₁ and S₂). Whereas, lower contents were found at 100 per cent substitution through inorganic source (S₁₀). Available zinc,

copper, iron and manganese contents were not influenced significantly by nitrogen substitution levels.

Nitrogen substitution level of S₅ recorded the highest gross return (Rs. 46,600/ha) and net returns (Rs. 34,806/ha) and were closely followed by S₇ and S₁₀. Benefit cost ratio was also highest with S₅. The lowest gross return (Rs. 39,763/ha), net return (Rs. 28,581/ha) and benefit:cost ratio (2.55) were obtained with S₉ and were very closely followed by S₁.

Thus, nitrogen substitution of 25 to 50 per cent with distillery effluents (liquid and solid effluents) resulted in higher grain yield which was comparable with 100 per cent substitution through inorganic source and hence 25 to 50 per cent cost on inorganic fertilizer could be saved in both maize and wheat. Improvement in chemical properties should not be overlooked in the substitution levels substituted with 100 per cent through distillery effluents, however, these substitution levels could not meet the nitrogen requirement fully for adequate growth and yield of the crops. Thus, the use of both distillery effluents and inorganic source in supplementing nitrogen assumes special significance.

Significantly higher grain yield of maize was recorded in 1:5 dilution level (76.82 q/ha) which was comparable with 1:10 dilution level but both were significantly higher than irrigation by good water (66.97 q/ha). Grain yield at 1:5 dilution level accounted to 14.72 per cent higher over irrigation by good water. A decreasing trend in yield was noticed at higher dilution levels. Irrigation by undiluted effluent resulted in significantly lowest grain yield (24.06). All the yield components such as cob length, cob girth, weight per cob, number of grains per cob, grain

weight per cob and test weight were significantly higher at lower dilution level of 1:5, resulting higher grain yield.

Similarly, growth parameters such as plant height, leaf area, leaf area index, leaf area duration, total dry matter production and its accumulation in different parts were higher at lower dilution level of 1:5. However, all these parameters were drastically reduced at irrigation by undiluted effluent resulting in lesser growth and yield. Lesser days for 50 per cent tasseling were recorded at lower dilution levels than higher ones.

Significantly maximum stover yield (106.77 q/ha) was recorded at 1:5 dilution level followed by 1:10 dilution level (104.75 q/ha). Whereas, significantly lowest stover yield (36.87 q/ha) was recorded at irrigation by undiluted effluent. Similarly, harvest index also followed the same trend.

Quality of produce improved under lower dilution levels in terms of protein and reducing sugar as compared to higher dilution levels. Plants at lower dilution levels recorded higher nitrogen, phosphorus and potassium contents at anthesis as compared to higher dilution levels. Even at harvest, higher values of nitrogen, phosphorus and potassium in both grain and stover were noticed at lower dilution levels. Whereas, zinc, copper, iron and manganese contents either in grain or stover did not differ significantly. However, total uptake of nitrogen, phosphorus, potassium, zinc, copper, iron and manganese were found higher again at lower dilution level of 1:5 than higher dilution levels.

Lower dilution levels resulted in significantly higher soil reaction, electrical conductivity, organic carbon, available nitrogen, phosphorus and potassium contents after harvest of the crop. Whereas, significantly lower value of bulk density was recorded at lower dilution levels than

higher dilution levels. Though zinc, copper, iron and manganese contents showed nonsignificant response, higher values were recorded at lower dilution levels.

The dilution level of 1:5 recorded the maximum gross return (Rs.36,976/ha) which was closely followed by 1:10 dilution level (Rs.36,111/ha). The maximum net return of Rs. 25,212/ha and the highest benefit cost ratio of 2.14 were obtained again with 1:5 and was closely followed by 1:10 (Rs.24,535/ha and 2.11, respectively). Whereas, the lowest net return (Rs.1,637/ha) and benefit:cost ratio (0.16) were realised with irrigation by undiluted effluent.

Differences among the dilution levels with regard to grain yield of wheat were significant. Significantly higher grain yield (52.59 q/ha) was obtained at higher dilution level of 1:50. While, the lower dilution levels of effluent registered significantly lower grain yields. Irrigation by undiluted effluent resulted significantly lowest grain yield of 10.56 q per ha. Higher grain yield with higher dilution level was due to better expression of growth and yield components such as total dry matter production and its accumulation in different parts, number of productive tillers, leaf area index, leaf area duration, number of days to 50 per cent heading, ear length, ear weight, number of grains per ear and test weight. Whereas, significantly lower values of all these parameters were recorded at lower dilution levels.

Higher dilution level of 1:50 recorded significantly higher straw yield (67.23 q/ha) followed by irrigation with good water (65.84 q/ha). Whereas, drastic reduction in straw yield was recorded at irrigation by undiluted effluent (20.39 q/ha).

Higher protein per cent, sedimentation values, wet gluten and dry gluten were recorded at lower dilution levels than higher dilution levels. Nutrient contents *viz.*, nitrogen, phosphorus and potassium content at anthesis were higher at lower dilution levels than higher levels. At harvest also, higher values of nitrogen, phosphorus and potassium contents were noticed in grain and stover at lower dilution levels than higher ones. Though, zinc, copper, iron and manganese showed nonsignificant response, higher values were noticed at lower dilution levels. The total uptake of all these nutrients were higher at higher dilution level of 1:50 than lower dilution levels.

Soil reaction, electrical conductivity and organic carbon were significantly higher at lower dilution levels. These lower dilution levels improved the bulk density of the soil. Again, available nitrogen, phosphorus, potassium, zinc, copper, iron and manganese contents in soil were significantly higher at lower dilution levels than higher ones.

Highest gross return was obtained with 1:50 dilution level (Rs.46,106/ha) which was closely followed by irrigation by good water (Rs.44,982/ha). The lowest gross return was recorded with irrigation by undiluted effluent (Rs.9,671/ha). The maximum net returns (Rs.34,232/ha) and highest benefit:cost ratio (2.88) were again obtained with dilution level of 1:50. Irrigation by undiluted effluent realised negative net return (Rs.1,001/ha) and negative benefit:cost ratio (0.09).

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Appendices

Appendix I

Correlation coefficient (r) between yield and important parameters of plant growth, yield, quality and soil properties in maize as influenced by nitrogen substitution through distillery effluents

Parameter	'r' value	Parameter	'r' value
Growth parameters		Nutrient content and property of soil	
Plant height (cm) at harvest	0.968**	Available nitrogen (kg per ha)	0.898*
Leaf area at harvest (dm ² per plant)	0.994**	Available phosphorus (kg per ha)	-0.770
Leaf area duration (days) at 90 DAS-harvest	0.993**	Available potassium (kg per ha)	-0.824*
Total dry matter production (dm ² per plant) at harvest	0.924**	Available zinc (ppm)	0.174
Days to 50 per cent tasseling	-0.732**	Available copper (ppm)	-0.674
Yield parameters		Available iron (ppm)	-0.777
Cob length (cm)	0.963**	Available manganese (ppm)	-0.853*
Cob girth (cm)	0.978**	PH	-0.627
Cob weight (g)	0.986**	Electrical conductivity (dSm ⁻¹)	-0.824*
Number of grains per cob	0.991**	Organic carbon (%)	0.162
Grain weight per cob (g)	0.987**	Bulk density (Mg per m ³)	0.549
Test weight (g per 100 grains)	0.980**		
Stover yield (q per ha)	0.941**		
Harvest index	0.995**		
Quality parameters			
Protein(%)	0.665*		
Reducing sugar (%)	-0.492		
Nutrient content at anthesis			
Nitrogen content (%)	0.507		
Phosphorus content (%)	-0.520		
Potassium content (%)	-0.636*		
Nutrient content and total uptake at harvest			
Nitrogen content in grain (%)	0.873		
Nitrogen content in stover (%)	0.815		
Potassium content in grain (%)	-0.747		
Potassium content in stover (%)	-0.883		
Nitrogen uptake (kg per ha)	0.991**		
Phosphorus uptake (kg per ha)	0.958**		
Potassium uptake (kg per ha)	0.943**		
Zinc uptake (kg per ha)	0.950**		
Copper uptake (kg per ha)	0.935**		
Iron uptake (kg per ha)	0.960**		
Manganese uptake (kg per ha)	0.958**		

* Significant at P = 0.05 : ** Significant at P = 0.01.

Appendix II

Correlation coefficient (r) between yield and important parameters of plant growth, yield, quality and soil properties in wheat as influenced by nitrogen substitution through distillery effluents

Parameter	'r' value	Parameter	'r' value
Growth parameters		Nutrient content and total uptake at harvest	
Plant height (cm) at harvest	0.970**	Nitrogen content in grain (%)	0.573
Leaf area index at 90 DAS	0.993**	Nitrogen content in straw (%)	0.676*
Leaf area duration at 60-90 DAS	0.989**	Potassium content in grain (%)	-0.814
Total dry matter production (g per m row length) at 90 DAS	0.996**	Potassium content in straw (%)	-0.863
Productive tillers (per metre row length)	0.992**	Nitrogen uptake (kg per ha)	0.976**
Yield parameters		Phosphorus uptake (kg per ha)	0.953**
Ear length (cm)	0.981**	Potassium uptake (kg per ha)	0.947**
Ear weight (g)	0.987**	Zinc uptake (kg per ha)	0.948**
Number of grains per ear	0.993**	Copper uptake (kg per ha)	0.935**
Test weight (g per 1000 grains)	0.980**	Iron uptake (kg per ha)	0.968**
Straw yield (q per ha)	0.941**	Manganese uptake (kg per ha)	0.950**
Harvest index	0.991**	Nutrient content and property of soil	
Quality parameters		Available nitrogen (kg per ha)	0.895*
Protein(%)	0.665*	Available phosphorus (kg per ha)	-0.753
Sedimentation value (ml)	0.690*	Available potassium (kg per ha)	-0.825*
Wet gluten (%)	0.768**	Available zinc (ppm)	0.185
Dry gluten (%)	0.785**	Available copper (ppm)	-0.622
Nutrient content at anthesis		Available iron (ppm)	-0.611
Nitrogen content (%)	0.536	Available manganese (ppm)	-0.850*
Phosphorus content (%)	0.515	pH	-0.576
Potassium content (%)	0.678*	Electrical conductivity (dSm ⁻¹)	-0.825*
		Organic carbon (%)	0.206
		Bulk density (Mg per m ³)	0.602

* Significant at P = 0.05 : ** Significant at P = 0.01.

Appendix III

Correlation coefficient (r) between yield and important parameters of plant growth, yield, quality and soil properties in maize as influenced by dilution of liquid distillery effluents with good water

Parameter	'r' value	Parameter	'r' value
Growth parameters		Nutrient content and total uptake at harvest	
Plant height (cm) at harvest	0.978**	Nitrogen content in grain (%)	-0.434
Leaf area at harvest (dm ² per plant)	0.961**	Nitrogen content in stover (%)	-0.394
Leaf area duration (days) at 90 DAS-harvest	0.936**	Potassium content in grain (%)	-0.346
Total dry matter production (dm ² per plant) at harvest	0.997**	Potassium content in stover (%)	-0.367
Days to 50 per cent tasseling	-0.400	Nitrogen uptake (kg per ha)	0.993**
Yield parameters		Phosphorus uptake (kg per ha)	0.978**
Cob length (cm)	0.989**	Potassium uptake (kg per ha)	0.649
Cob girth (cm)	0.987**	Zinc uptake (kg per ha)	0.951**
Cob weight (g)	0.996**	Copper uptake (kg per ha)	0.963**
Number of grains per cob	0.997**	Iron uptake (kg per ha)	0.971**
Grain weight per cob (g)	0.906**	Manganese uptake (kg per ha)	0.940**
Test weight (g per 100 grains)	0.994**	Nutrient content and property of soil	
Stover yield (q per ha)	0.981**	Available nitrogen (kg per ha)	-0.611
Harvest index	0.996**	Available phosphorus (kg per ha)	-0.356
Quality parameters		Available potassium (kg per ha)	-0.508
Protein(%)	-0.405	Available zinc (ppm)	-0.397
Reducing sugar (%)	-0.390	Available copper (ppm)	-0.522
Nutrient content at anthesis		Available iron (ppm)	-0.617
Nitrogen content (%)	-0.401	Available manganese (ppm)	-0.711
Phosphorus content (%)	-0.548	pH	-0.313
Potassium content (%)	-0.463	Electrical conductivity (dSm ⁻¹)	-0.690
		Organic carbon (%)	-0.676
		Bulk density (Mg per m ³)	0.369

* Significant at P = 0.05 : ** Significant at P = 0.01.

Appendix IV

Correlation coefficient (r) between yield and important parameters of plant growth, yield, quality and soil properties in wheat as influenced by dilution of liquid distillery effluents with good water

Parameter	'r' value	Parameter	'r' value
Growth parameters		Nutrient content and total uptake at harvest	
Plant height (cm) at harvest	0.804	Nitrogen content in grain (%)	-0.698
Leaf area index at 90 DAS	0.988**	Nitrogen content in straw (%)	-0.809
Leaf area duration at 60-90 DAS	0.981**	Potassium content in grain (%)	-0.737
Total dry matter production (g per m row length) at 90 DAS	0.996**	Potassium content in straw (%)	-0.756
Productive tillers (per metre row length)	0.998**	Nitrogen uptake (kg per ha)	0.973**
Days to 50% heading	0.992**	Phosphorus uptake (kg per ha)	0.969**
Yield parameters		Potassium uptake (kg per ha)	0.885*
Ear length (cm)	0.993**	Zinc uptake (kg per ha)	0.951**
Ear weight (g)	0.987**	Copper uptake (kg per ha)	0.937**
Number of grains per ear	0.998**	Iron uptake (kg per ha)	0.947**
Test weight (g per 1000 grains)	0.987**	Manganese uptake (kg per ha)	0.933**
Straw yield (q per ha)	0.888	Nutrient content and property of soil	
Harvest index	0.751	Available nitrogen (kg per ha)	-0.851*
Quality parameters		Available phosphorus (kg per ha)	-0.807
Protein(%)	-0.705	Available potassium (kg per ha)	-0.837*
Sedimentation value (ml)	-0.795	Available zinc (ppm)	-0.681
Wet gluten (%)	-0.793	Available copper (ppm)	-0.820*
Dry gluten (%)	-0.790	Available iron (ppm)	-0.876*
Nutrient content at anthesis		Available manganese (ppm)	-0.853*
Nitrogen content (%)	-0.895*	pH	-0.673
Phosphorus content (%)	-0.807	Electrical conductivity (dSm ⁻¹)	-0.871*
Potassium content (%)	-0.883*	Organic carbon (%)	-0.808
		Bulk density (Mg per m ³)	0.784

* Significant at P = 0.05 : ** Significant at P = 0.01.

Appendix V

Price of inputs and outputs

Sl.No.	Particular	Price (Rs.)
I.	INPUTS	
1.	Seed material	
	Maize	15/kg
	Wheat	12/kg
2.	Fertilizers	
	Urea	360/q
	Single super phosphate	300/q
	Muriate of potash	450/q
3	Effluents	
	Solid effluent	50/t
4.	Labour wages per day of 8 hrs	
	Men labour	40
	Women labour	35
	Bullock pair	120
5.	Irrigation charge	75/irrigation/ha
II.	OUTPUTS	
1.	Maize	
	a. Grain	450/q
	b. Stover	225/t
2.	Wheat	
	a. Grain	800/q
	b. Straw	60/q

AGRONOMIC INVESTIGATION ON USE OF DISTILLERY EFFLUENT ON THE PERFORMANCE OF RABI MAIZE AND WHEAT

SUKANYA, T.S.

2002

Dr. S.S. MELI
MAJOR ADVISOR

ABSTRACT

Field investigations were carried out during *rabi* seasons of 1999-2000 and 2000-2001 on farmer's field beside Sri Lakshmi Narayana Distillery Unit, Garag which is located 8 km away from Main Research Station, University of Agricultural Sciences, Dharwad. Experiment 1 with *rabi* maize and Experiment 2 with wheat were conducted to study the effect of distillery effluent as a source of nitrogen in different proportions with inorganic nitrogen. Treatments included 10 nitrogen substitution levels replicated thrice. Experiment 3 with *rabi* maize and Experiment 4 with wheat were conducted to study the effect of graded dilution of liquid distillery effluent as a source of irrigation in conjunction with good water and treatments included 6 dilution levels replicated four times.

In first two experiments, significantly higher grain yield of maize (70.17 q/ha) and wheat (53.14 q/ha) were obtained with higher net returns at S₅ (50% N through solid effluent + 50% N through inorganic source) which found on par with S₇ (25% N through solid effluent + 75% N through inorganic source) and S₁₀ (100% N through inorganic source). Whereas, the lowest maize (62.81 q/ha) and wheat grain yields (45.01 q/ha) were recorded with S₉ (25% N through solid effluent + 75% N through liquid effluent) with lesser net returns. Higher yield with S₅ was mainly due to better expression of growth and yield components of both crops. Similarly, quality of maize and wheat grains was superior with S₅. Nitrogen substitution through effluents did not cause significant changes in soil pH, EC, OC and BD. However, higher contents of available soil nitrogen, phosphorus and potassium were recorded with S₉.

In Experiment 3 and 4, significantly higher grain yield in maize (76.82 q/ha) and wheat (52.59 q/ha) were recorded with higher net returns at dilution levels of 1:5 and 1:50 (liquid effluent : good water), respectively. Quality of maize and wheat grains was superior with undiluted effluent irrigated plots. Soil pH, EC, OC, available nitrogen, phosphorus and potassium and micronutrients increased with decrease in dilutions.