

**STUDIES ON FORTIFICATION OF DISTILLERY
SPENTWASH FOR FOLIAR APPLICATION AND ITS
EFFECT ON SOIL PROPERTIES, GROWTH AND
YIELD OF TOMATO**

SAVITHA, H. R.

PALB 2094

**DEPARTMENT OF SOIL SCIENCE AND
AGRICULTURAL CHEMISTRY
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU - 560 065**

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SAVITHA, H. R.

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*Affectionately dedicated
to My beloved Husband
Dr.G.C.Shashidhara and
Daughter Ganika*

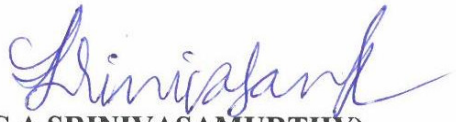


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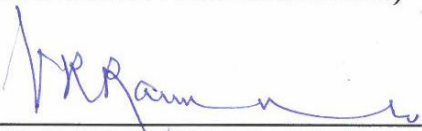
This is to certify that the thesis entitled “STUDIES ON FORTIFICATION OF DISTILLERY SPENTWASH FOR FOLIAR APPLICATION AND ITS EFFECT ON SOIL PROPERTIES, GROWTH AND YIELD OF TOMATO” submitted by Mrs. SAVITHA, H.R., ID No. PALB 2094 for the degree of DOCTOR OF PHILOSOPHY in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY to the University of Agricultural Sciences, Bengaluru, is a record of research work done by her during the period of her study in this University under my guidance and supervision, and the thesis has not previously formed the basis of the award of any other degree, diploma, associateship, fellowship or similar other titles.

**Bengaluru
July, 2015**


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GROWTH AND YIELD OF TOMATO
SAVITHA, H. R.**

ABSTRACT

Laboratory and green house experiments were conducted at University of Agricultural Sciences, GKVK, Bengaluru during 2013 to study the growth regulating properties of distillery spentwash on tomato, cowpea and sunflower with twelve treatments, replicated thrice using CRD design. Higher seed germination (%) and seedling growth parameters were noticed in treatments which received diluted distillery spentwash from 1:5 dilution onwards upto 1:10 dilution in both experiments. Based on pot experiment results, two field experiments were conducted in a farmer's field at Gurudevarahalli, Mandya district during 2013 and 2014 to study the effect of foliar application of diluted and fortified distillery spentwash on soil properties, growth and yield of tomato crop with thirteen and eleven treatments replicated thrice using RCBD design. In field experiment on diluted spentwash, 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher fruit yield (78.9 t ha⁻¹, respectively). After harvest of each crop, soil properties like EC (0.41dS m⁻¹), OC (0.76 %) available N (271.3 kg ha⁻¹), P₂O₅ (35.7 kg ha⁻¹), K₂O (389.8 kg ha⁻¹), secondary and micronutrients were higher in treatment which received 100% RDF + 5 sprays of undiluted distillery spentwash and pH was higher (7.81) in treatment which received water spray. Significantly lower fruit (55.7 t ha⁻¹) yield was recorded in treatment with water spray. In the field experiment on fortified spenwash treatment receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval recorded significantly higher fruit yield (83.0 t ha⁻¹). Significantly lower fruit yield (64.8 t ha⁻¹) and higher values of soil pH (7.98), EC (0.38 dSm⁻¹), OC (0.78 %), primary, secondary and micronutrients were observed in treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Department of SS and AC

Date: 30.7.2015

Place: Bengaluru

Signature of the Chairman

(C. A. Srinivasamurthy)

ಮಣ್ಣಿನ ಗುಣ ಲಕ್ಷಣಗಳು, ಟೊಮ್ಯಾಟೋ ಬೆಳೆಯ ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಯ ಮೇಲೆ
ಪೋಷಕಾಂಶಗಳನ್ನು ವರ್ಧಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರಿನ ಸಿಂಪರಣೆಯ ಪರಿಣಾಮದ ಕುರಿತು ಅಧ್ಯಯನ

ಸವಿತ ಹೆಚ್. ಆರ್

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಟೊಮ್ಯಾಟೋ, ಸೂರ್ಯಕಾಂತಿ ಮತ್ತು ಅಲಸಂದೆ ಬೀಜಗಳ ಮೊಳಕೆ ಮತ್ತು ಮೊಳಕೆಯ ಬೆಳವಣಿಗೆಯನ್ನು ಕ್ರಮಬದ್ಧಗೊಳಿಸಲು ವಿವಿಧ ಪ್ರಮಾಣದಲ್ಲಿ ನೀರನ್ನು ಮಿಶ್ರಣ ಮಾಡಿ ತಯಾರಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರನ್ನು ಬಳಸಿ ಪ್ರಯೋಗ ಶಾಲೆ ಮತ್ತು ಹಸಿರು ಮನೆಯಲ್ಲಿ 2013ರಲ್ಲಿ ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯ ಬೆಂಗಳೂರಿನಲ್ಲಿ 12 ಉಪಚಾರಗಳನ್ನು ಸಿ.ಆರ್.ಡಿ. ಮಾದರಿಯಲ್ಲಿ ಮೂರು ಬಾರಿ ಪುನರಾವರ್ತಿಸಿ ಸಂಶೋಧನೆ ನಡೆಸಲಾಯಿತು. ಈ ಎರಡು ಪ್ರಯೋಗಗಳ ಪ್ರಕಾರ ಹೆಚ್ಚಿನ ಬೀಜಮೊಳಕೆ ಮತ್ತು ಮೊಳಕೆಯ ಬೆಳವಣಿಗೆಯು ವಿವಿಧ ಪ್ರಮಾಣದಲ್ಲಿ ನೀರನ್ನು ಮಿಶ್ರಣಮಾಡಿ ತಯಾರಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರಿನ ಅನುಪಾತ 1:5 ರಿಂದ ಅನುಪಾತ 1:10ರ ವರೆಗೆ ಸಿಂಪರಣೆ ಮಾಡಿದ ಉಪಚಾರದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಹಸಿರುಮನೆ ಪ್ರಯೋಗದಿಂದ ಬಂದ ಫಲಿತಾಂಶದ ಮೇಲೆ ಎರಡು ಕ್ಷೇತ್ರ ಪ್ರಯೋಗಗಳನ್ನು 2013 ಮತ್ತು 2014ರ ಅವಧಿಯಲ್ಲಿ ಮಂಡ್ಯ ಜಿಲ್ಲೆಯಲ್ಲಿರುವ ಗುರುದೇವರ ಹಳ್ಳಿಯ ರೈತರ ಜಮೀನಿನಲ್ಲಿ ನಡೆಸಲಾಯಿತು. ಮಣ್ಣಿನ ಗುಣಲಕ್ಷಣಗಳು ಬೆಳೆಗಳ ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿಯ ಮೇಲೆ ನೀರು ಮಿಶ್ರಿತ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ದ್ರಾವಣ ಮತ್ತು ಪೋಷಕಾಂಶಗಳನ್ನು ವರ್ಧಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ದ್ರಾವಣದ ಬಳಕೆಯಿಂದಾಗುವ ಪರಿಣಾಮಗಳನ್ನು ಪರೀಕ್ಷಿಸಲು ಹದಿಮೂರು ಮತ್ತು ಹನ್ನೊಂದು ಉಪಚಾರಗಳನ್ನು ಆರ್.ಸಿ.ಬಿ.ಡಿ. ಮಾದರಿಯಲ್ಲಿ ಮೂರು ಬಾರಿ ಪುನರಾವರ್ತಿಸಿ ಎರಡು ಕ್ಷೇತ್ರ ಪ್ರಯೋಗಗಳನ್ನು ನಡೆಸಲಾಯಿತು. ತಿಳಿ ಮಾಡಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರಿನ ಕ್ಷೇತ್ರ ಪ್ರಯೋಗದಲ್ಲಿ ಶೇ. 100 ಶಿಫಾರಸಿತ ಪ್ರಮಾಣದ ರಸಗೊಬ್ಬರ + ನೀರನ್ನು 1:5 ಅನುಪಾತದಲ್ಲಿ ಬಳಸಿ ತಯಾರಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರನ್ನು ಬೆಳೆಗಳಿಗೆ ಐದು ಬಾರಿ ಸಿಂಪಡಿಸಿದ ಉಪಚಾರದಲ್ಲಿ ಗಮನಾರ್ಹವಾಗಿ ಹೆಚ್ಚಿನ ಟೊಮ್ಯಾಟೋ ಹಣ್ಣಿನ (78.9 ಟಿ./ಹೆ.) ಇಳುವರಿ ಕಂಡುಬಂದಿದೆ. ಹಾಗೆಯೇ ಮಣ್ಣಿನ ಗುಣಲಕ್ಷಣಗಳಾದ ವಿದ್ಯುದ್ವಾಹಕತೆ (0.41 ಡೆಸಿ ಸೀಮೆನ್ಸ್/ಮೀ.), ಸಾವಯವ ಇಂಗಾಲ 0.76%, ಲಭ್ಯವಿರುವ ಸಾರಜನಕ (271.3 ಕಿ.ಗ್ರಾಂ./ಹೆ.), ರಂಜಕ (35.7 ಕಿ.ಗ್ರಾಂ./ಹೆ.), ಪೊಟ್ಯಾಷಿಯಂ (389.8 ಕಿ.ಗ್ರಾಂ./ಹೆ.), ದ್ವಿತೀಯ ಮತ್ತು ಲಘು ಪೋಷಕಾಂಶಗಳು ಶೇ.100 ಶಿಫಾರಸಿತ ಪ್ರಮಾಣದ ರಸಗೊಬ್ಬರ + ತಿಳಿ ಮಾಡಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರನ್ನು ಬೆಳೆಗಳಿಗೆ ಐದು ಬಾರಿ ಸಿಂಪಡಿಸಿದಾಗ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಹಾಗೆಯೇ, ಹೆಚ್ಚಿನ ರಸಸಾರ (7.81) ಮತ್ತು ಕಡಿಮೆ ಹಣ್ಣಿನ ಇಳುವರಿಯು (55.7 ಟಿ./ಹೆ.) ಐದುಬಾರಿ ನೀರನ್ನು ಸಿಂಪಡಿಸಿದ ಉಪಚಾರದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಪೋಷಕಾಂಶಗಳನ್ನು ವರ್ಧಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರಿನ ಕ್ಷೇತ್ರ ಪ್ರಯೋಗದಲ್ಲಿ ಬೇರೆ ಉಪಚಾರಗಳಿಗೆ ಹೋಲಿಸಿದರೆ ಹೆಚ್ಚಿನ ಟೊಮ್ಯಾಟೋ ಹಣ್ಣಿನ ಇಳುವರಿಯು (83 ಟಿ./ಹೆ.) ಶೇ. 85 ಶಿಫಾರಸಿತ ಸಾರಜನಕವನ್ನು ರಸಗೊಬ್ಬರಗಳ ಮೂಲಕ + ಶೇ. 15 ಶಿಫಾರಸಿತ ಸಾರಜನಕವನ್ನು ದ್ರವ ರೂಪದ ಅಮೋನಿಯಾ, ಸತು ಮತ್ತು ಬೋರಾನ್‌ನ್ನು ವರ್ಧಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರನ್ನು ಮೂರು ಬಾರಿ 20 ದಿನಗಳ ಅಂತರದಲ್ಲಿ ಸಿಂಪಡಿಸಿದ ಉಪಚಾರದಲ್ಲಿ ಕಂಡುಬಂದಿದೆ. ಗಮನಾರ್ಹವಾಗಿ ಕಡಿಮೆ ಹಣ್ಣಿನ ಇಳುವರಿ (64.8 ಟಿ./ಹೆ.) ಮತ್ತು ಮಣ್ಣಿನ ಗುಣಲಕ್ಷಣಗಳಾದ ರಸಸಾರ (7.98), ವಿದ್ಯುದ್ವಾಹಕತೆ (0.38 ಡೆಸಿ ಸೀಮೆನ್ಸ್/ಮೀ.), ಸಾವಯವ ಇಂಗಾಲ (0.78%), ಪ್ರಥಮ, ದ್ವಿತೀಯ ಮತ್ತು ಲಘು ಪೋಷಕಾಂಶಗಳು ಶೇ. 70 ಶಿಫಾರಸಿತ ಸಾರಜನಕವನ್ನು ರಸಗೊಬ್ಬರಗಳ ಮೂಲಕ + ಶೇ.30 ಶಿಫಾರಸಿತ ಸಾರಜನಕವನ್ನು ದ್ರವರೂಪದ ಅಮೋನಿಯಾವನ್ನು ವರ್ಧಿಸಿದ ಡಿಸ್ಟಿಲರಿ ತ್ಯಾಜ್ಯ ನೀರನ್ನು ಆರು ಬಾರಿ, ಹತ್ತು ದಿನಗಳ ಅಂತರದಲ್ಲಿ ಸಿಂಪಡಿಸಿದ ಉಪಚಾರದಲ್ಲಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ.

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ಮುಖ್ಯ ಸಲಹೆಗಾರರು

ಡಾ|| ಸಿ. ಎ. ಶ್ರೀನಿವಾಸಮೂರ್ತಿ

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I INTRODUCTION

One of the most important environmental problems faced by mankind is management of wastes. Industrial processes create a variety of wastes including both liquid wastes and solid wastes which are difficult and costly to handle and dispose off in a non polluting way. Wastewater characteristics and levels of pollutants vary significantly from industry to industry. Now-a-days, emphasis is laid on waste minimization and revenue generation through byproduct recovery or alternative uses. Pollution prevention focuses on preventing the generation of wastes, while waste minimization refers to reducing the volume of toxic or hazardous wastes by water recycling and reuse and process modifications and the byproduct recovery as a fall out of manufacturing process creates ample scope for revenue generation through scientific approach thereby offsetting the costs substantially.

Molasses an important byproduct of sugar industry is the main raw material for the production of alcohol in distilleries by fermentation method. The aqueous distillery effluent known as spentwash is a dark brown coloured, organic effluent and is approximately 12-15 times by volume of the product alcohol. Increasing number of industries in India has resulted in substantial increase in pollutants load affecting our environment. Among various industries, molasses based industries (distilleries) occupy a prominent place in Indian economy. The distilleries are considered as a major polluter of the environment and distilleries are one of the 17 most polluting industries listed by the Central Pollution Control Board. At present, there are 319 distilleries in India with an installed capacity of 3.29 billion litres of alcohol per year (Piyush Malaviya and Anuradha Sharam, 2011).

In India, about 40 billion liters of raw spentwash is discharged annually from distilleries, which is characterized by undesirable color, foul odor, high biological oxygen demand (BOD:39000-42000 mg L⁻¹) and chemical oxygen demand (COD: 79000- 92000 mg L⁻¹) (Joshi, 1994). Raw spentwash is normally discharged into open land or near by water bodies resulting in environmental, soil and underground water pollution (including threat to plant and human/animal lives). The raw spentwash is highly acidic and contains easily oxidisable organic matter. Distillery spentwash has higher concentration of potassium, nitrogen and other plant nutrients (Ramadurai and Gerard, 1994). Biomethanation plant in distilleries has reduced the oxygen demand of raw spentwash and the resulting spentwash obtained is referred to as primary treated spentwash (PTSW). Primary treatment of spentwash increases the nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na) and micronutrients content (Zalawadia *et al.*, 1997).

With the current emphasis on environmental health and water pollution issues, there is an increased awareness on the need to dispose spentwash safely and beneficially. Use of spentwash in agriculture could be an important consideration. However, safe disposal of industrial effluents on land for irrigation is comparatively a new area of research and hence throws new challenges for environmental management (Buechler and Mekala, 2005). Research to reduce deleterious effects of industrial effluents on life and

surrounding environment should be given top priority before its disposal. The approach should provide environmentally compatible solution to water pollution problems and augment the traditional irrigational resources for the development of sustainable agriculture. Industrial effluents contain large amounts of nutrients as well as toxic elements. Plants are being used as ecological monitors to assess the toxicity of pollutants.

In India, the use of distillery spentwash in agriculture is popular since the inception of the industry. In water scarce situation, spentwash is an important water source for irrigation and at lower concentrations cause less harm in this context studies have been carried out by many researchers (Rani and Srivastava, 1990; Subramani *et al*, 1995; Srinivasamurthy *et al*, 2006; Pandey *et al*, 2008).

The farmers around the distillery unit use effluent for irrigation purpose however farmers who have used undiluted effluent have lost their crop. There have been studies related to the application of distillery spentwash as irrigation source in India as well as other parts of the world. Spentwash at the rate of 35-50 m³ ha⁻¹ was recommended as optimum dose for higher sugarcane yield in Brazil and Australia. In Sao Paulo, Brazil, the crop productivity was 2-10 times higher with distillery spentwash irrigation as compared to the untreated lands. Distillery spentwash increased cane yield in sugarcane and decreased the potassium fertilizer requirement in a study conducted by scientists at Caroni Research Station, Trinidad and Tobago. In India, extensive studies on distillery spentwash have been carried out successfully with respect to irrigation in different agro-climatic regions. But studies on foliar application of distillery spentwash are inadequate. The undiluted distillery spentwash contains an excess of various types of cations and anions, which are injurious to plant growth and these constituents should be reduced to beneficial level by diluting the spentwash with water and then used as a substitute for chemical fertilizer. Hence, there is need to identify the best dilution level for foliar application to different crops especially vegetable crops like tomato which requires very high quantity of nutrients.

Tomato (*Lycopersicon esculentum* Mill, 2n=24), a popular solanaceous vegetable crop, is cultivated throughout the world. It ranks third in the world's vegetable production, next to potato and sweet potato, and thus ranks first as processing crop among the vegetables. Tomato is consumed either as fresh, cooked or as processed products like juice, ketchup, sauce, puree and paste etc., Tomato fruits are rich source of lycopene, vitamin 'A', vitamin 'C', minerals and organic acids.

Tomato is grown on a large scale in USA, Russia, Italy, Spain, Turkey, India and other Asian countries. In India, it is mainly cultivated in the states of Uttar Pradesh, Karnataka, Maharashtra, Haryana, Punjab, Bihar and West Bengal. In Karnataka, it is mainly grown in Kolar, Chikkaballapur and Bangalore districts.

The nutrient requirement of plants is met mainly through uptake from soil. However, most of the plant parts are able to absorb nutrients in ionic form from solution. Compared to roots, the leaves are able to take up only relatively small quantities of nutrients, but foliar nutrition is highly beneficial when used as a supplement to soil

fertilization. Foliar nutrition plays an important role in increasing the crop yields, especially when roots are unable to provide plants with adequate nutrients.

Tomato is grown traditionally in open condition with essential nutrients being provided as preplant fertilization and in the later growth stages by top dressing to the root zone. According to literature foliar spraying is an efficient method of nutrient supply during the intensive stage of tomato growth.

The effect of foliar plant nutrition is highly dependent on plant species, physical and chemical properties of nutrient solution as well as growing conditions. In general, the response of iris plants to foliar nutrition is adversely affected by nutrient status of soil (Khalifa *et al.* 2011).

In order to utilize distillery spentwash as a supplement to fertilizers and to increase the yield and enhance the quality of tomato, there is need to develop technology to process this effluent efficiently and economically which will eventually fulfil the grower's as well as consumer's needs. Studies on management practices, particularly on (a) the management of nutrients through dilution of distillery spentwash with water and (b) fortification of distillery spentwash with nitrogen, boron and zinc would help in increasing growth, yield and quality of tomato. But the information available on these aspects under Indian conditions is inadequate.

Considering the above facts, present investigation entitled “***Studies on fortification of distillery spentwash for foliar application and its effect on soil properties, growth and yield of tomato***” was carried out with the following objectives:

1. To study the growth regulating properties of spentwash through bioassay.
2. To study the effect of different dilution of distillery spentwash as a foliar spray on growth and yield of tomato and on soil properties.
3. To determine the optimum proportion of nutrients for preparation of fortified spentwash and to study the effect of fortified spentwash on growth and yield of tomato and soil properties.

II REVIEW OF LITERATURE

Effective waste water management through eco-friendly technologies is the need of the hour. Liquid (effluent) and solid (sludge) wastes are continuously generated in huge quantities from various industries. Indiscriminate disposal of these wastes has resulted in a series of well documented environmental problems in India.

In India, about 40 billion liters of raw spentwash is annually discharged from distilleries which is characterized by undesirable color, foul odor, high biological oxygen demand and chemical oxygen demand. Raw spentwash is normally discharged into open land or near by water bodies resulting in soil and underground water pollution which in turn becomes threat to plant and human/animal lives. The raw spentwash is highly acidic and contains easily oxidisable organic matter. Distillery spentwash has high content of potassium and other plant nutrients. By subjecting the spentwash to biomethanation process, the oxygen demand of raw spentwash can be reduced appreciably. The resulting spentwash obtained is called primary treated spentwash (PTSW) and the primary treatment of raw spentwash decreases the calcium, magnesium, sodium, chloride and sulphate content and increases the potassium, sulphur, nitrogen, phosphorus as well as easily biodegradable organic matter. The higher concentration of salts in spentwash causes delay in seed germination, affects seedling growth and chlorophyll content of crops and the spentwash could safely be used for irrigation purpose only at low concentration. Diluted spentwash could be used for irrigation purpose without adversely affecting soil fertility and crop productivity. Irrigation with diluted effluent improves the physical and chemical properties of the soil and also increases the soil microflora.

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

- 2.1 Characterization of distillery spentwash.
- 2.2. Effect of distillery spentwash on seed germination and seedling growth.
- 2.3. Effect of foliar application of diluted distillery spentwash on growth, yield and quality of crops.
- 2.4. Effect of foliar application of nutrients on growth, yield and quality of crops
- 2.5. Effect of application of distillery spentwash on soil properties

2.1 Characterization of distillery spentwash

Molasses, a by-product of sugar industries is being used as raw material in distilleries for the production of alcohol which gives considerable income for these industries. However, for every liter of alcohol produced, about 10-15 liters of waste water (spentwash) is produced which pose major disposal problem. The distillery industrial waste water is non-toxic, biodegradable, purely of plant origin and contains large

quantities of soluble organic matter and plant nutrients, which the sugar cane plant has absorbed from the soil. Disposal of spentwash is causing environmental problems due to high BOD and COD, but contains valuable macro and micro nutrient elements, hence it can be considered as a liquid fertilizer.

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

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

The spentwash was highly acidic and carried a huge amount of organic load. Different constituent values are total solids (9000-15000 mg L⁻¹), COD (115000-120000 mg L⁻¹), total nitrogen: 1800 to 2000 mg L⁻¹ and phosphates: 2000 to 2100 mg L⁻¹. It had a considerable amount of SO₄²⁻ and Cl⁻, (3000 to 4000 and 7000 to 8000 mg L⁻¹, respectively) (Vaidyanathan *et al.*, 1995).

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

Zalawadia *et al.* (1997) stated that spentwash had a very high EC (29 dS m⁻¹) and was neutral in reaction (7.20), sodium adsorption ratio was 4.17 and Ca²⁺, Mg²⁺, K⁺, NO₃⁻, HCO₃⁻, SO₄²⁻ and Cl⁻ values were 58.8, 34.5, 170.8, 28.5, 35.0, 195.2 and 65.5 m moles L⁻¹, respectively. It had total N, P and K content of 1200, 900 and 6681 mg L⁻¹ respectively. Fe, Mn, Zn and Cu contents were 61.26, 4.00, 1.17 and 0.78 mg L⁻¹, respectively. Higher organic load in spentwash is the problem (BOD and COD, 2500 mg L⁻¹ and 6000 mg L⁻¹, respectively).

Pathak *et al.* (1999) reviewed the data on characteristics of the distillery spentwash. It has a neutral reaction (pH 6.9), alkalinity (CaCO₃ 491.3 mg L⁻¹), total dissolved solids (128.0 mg L⁻¹), volatile suspended solids (113.00 mg L⁻¹) with high COD (2152 mg L⁻¹), soluble COD (1740 mg L⁻¹) and BOD (1002 mg L⁻¹). Spentwash contained almost all the elements required by the plants like SO₄, Cl, Na, K and Ca, with concentrations of 46.0, 18.5, 100.0, 91.0 and 438.0 mg L⁻¹, respectively.

Jagdish Thampi and Aniruddha Pandit (1999) analyzed the physical properties of effluent such as, density, surface tension and boiling point. Density and boiling point of the concentrated distillery spentwash increased with an increase in solid concentration but variation in surface tension with respect to solid concentration. Increase the solid concentration resulted in decrease in surface tension of concentrated distillery spentwash.

Analytical data of raw distillery effluent collected from Coimbatore Alcohols and Chemicals Ltd., situated on the banks of river Bhavani were reviewed by Kailasam *et al.* (2001). The parameters were pH (8.57), electrical conductivity (36.07 dSm^{-1}), total suspended solids (9200 mg L^{-1}), total dissolved solids (10230 mg L^{-1}), chlorides (6748 mg L^{-1}), sulphates (80 mg L^{-1}), BOD (1400 mg L^{-1}), COD (1400 mg L^{-1}), volatile suspended solids (2450 mg L^{-1}) and potassium (4560 mg L^{-1}).

Sukanya and Meli (2003) observed that distillery effluent was dark brown in colour with unpleasant smell. The pH was 3.5 to 4.5, EC 20.8 dS m^{-1} , OC 0.8 per cent, TSS 380 mg L^{-1} , BOD 4620 mg L^{-1} , COD $26\,000 \text{ mg L}^{-1}$, N 1000 to 2000 mg L^{-1} , total P 30 to 50 mg L^{-1} , K 9000 to 13000 mg L^{-1} , bicarbonates 150 mg L^{-1} , sulphates 4.2 mg L^{-1} , along with other secondary and micronutrients.

Chemical composition of untreated and primary treated distillery spentwash was studied by Haron and Bose (2004). There was a considerable change in the chemical composition of untreated and primary treated spentwash with acidic (3.8) and alkaline (8.0) reaction, respectively. Electrical conductivity of untreated and primary treated spentwash was 30 and 32.5 dS m^{-1} , respectively. The total solids content in untreated and primary treated spentwash samples were 90,000 and $81,000 \text{ mg L}^{-1}$, respectively. The concentration of other nutrients in mg L^{-1} were nitrogen: 1500 (untreated) and 1740 (primary treated), phosphorus: 260 (untreated) and 260 (primary), potassium: 10000 (untreated) and 11500 (primary), calcium: 7000 (untreated) and 10500 (primary), magnesium: 3300 (untreated) and 2200 (primary), sodium: 400 (untreated) and 510 (primary), chloride: 5000 (untreated) and 11200 (primary) and the sulphate content of untreated spentwash was: 5000 and primary: 2400 mg L^{-1} .

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

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

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

Sandeep *et al.* (2007) observed that spentwash was red brown in colour with unpleasant odour of indol, sketol and other sulphur compounds. Temperature of distillery effluent was 28.5°C . The average pH value of the distillery effluent was 6.4. The range of dissolved oxygen in the distillery effluent was nil, meanwhile the recommended BIS range was 4-6. The absence of dissolved oxygen was possibly due to high organic load, the average value of total solid in distillery effluent was ~ 255 far from the BIS recommended range of 100. The value of BOD in distillery effluent was 544.4 and the recommended value of BIS was about 30. The COD value of the Distillery effluent was 2433.3 mg L^{-1} while the recommended level by BIS was 250 only; this high amount of COD and BOD was due to high organic load.

Kamlesh *et al.* (2007) analyzed treated distillery and sugar factory mixed effluent for its chemical composition. Effluent was slightly acidic and high in COD, BOD, sulphate, sulphide, chloride, TDS, TSS, oil and grease.

Pandey *et al.* (2008) analyzed distillery effluent for physico chemical properties. The effluent was wine red in colour and highly acidic (pH ~ 5.5) and possessed decaying alcoholic smell. The effluent contained high values of different pollution parameters, particularly total solids, 3450 mg l^{-1} (soluble plus suspended solids), alkalinity 1500 mg l^{-1} , biological oxygen demand (BOD, 1649 mg l^{-1}) and chemical oxygen demand (COD, 2036 mg l^{-1}). It had very low values of dissolved oxygen (DO, 0.34 mg l^{-1}). The heavy metals (Cd, Cr, Ni and Zn) content, particularly the nickel concentration (0.029 mg l^{-1}) was high.

Piyush Malaviya and Anuradha Sharma (2011) reported that the average values of various physico chemical characteristics of the 100% distillery effluent exhibited high chemical oxygen demand (2496 mg L^{-1}), chloride concentration ($\text{Cl}^{-} 799.7 \text{ mg L}^{-1}$), total dissolved solids (1408 mg L^{-1}) and osmotic pressure (0.79 atmosphere). The different concentrations of the effluent showed increasing trend of EC (electrical conductivity), OP and TDS with increasing concentration of the effluent. Minimum values of EC (0.8 mS cm^{-1}), OP (0.29 atmosphere) and TDS (512 mg L^{-1}) were observed in 20% effluent concentration (E20), while maximum values were detected in 100% effluent concentration (E100) i.e. 2.2 mS cm^{-1} EC, 0.79 atmosphere OP and 1408 mg L^{-1} TDS. There was a decreasing trend of pH with increasing concentrations of the effluent with highest pH (6.93) in 20% effluent and lowest (5.53) in 100% effluent concentration.

Kamini *et al.* (2012) analyzed the physico-chemical characteristics of the effluent and reported that it was alkaline and rich in chlorides and total dissolved solids (TDS). The distillery effluent was red brown in colour because of presence of reducing sugars and amino compounds, so called melanoidins and polyphenolic compounds or complexes of polyphenolic compounds. The higher values of BOD and COD may due to the

presence of high organic load and chemical substances such as resin, caustic soda. The value of COD may vary depending on the composition of organic non-sugar proteins and hemi-cellulose gums in the spentwash produced during processing.

Anuradha Mehta and Nagendra Bhardwaj (2012) reported that untreated effluent samples were high in certain parameters like EC (130200 $\mu\text{mho/cm}$), TDS (83400 mg l^{-1}), oil and grease (9 mg l^{-1}), total hardness (848 mg l^{-1}) and chloride (505.52 mg l^{-1}) COD(224 mg l^{-1}) and BOD(55 mg l^{-1}) than treated distillery effluent.

Chandraju *et al.* (2012) reported that the pH of distillery spentwash increased due to increase in dilution but EC, total solids, BOD, COD and other nutrients were decreased with an increase in the dilution of distillery spentwash.

Radha Jain and Srivatsava (2012) compared the crude and digested distillery spentwash with higher concentrations of essential nutrients (P, S, Fe, Mn, Zn, Cu) and heavy metals (Cd, Cr, Ni and Pb) were present in crude spentwash (CSW) as compared to the digested spentwash (DSW). Sulphur content was the highest (765 $\mu\text{g ml}^{-1}$ in DSW and 1,609 $\mu\text{g ml}^{-1}$ in CSW) among all nutrients analyzed.

2.2. Effect of distillery spentwash on seed germination and seedling growth

The research work on the impact of application of diluted distillery spentwash on seed germination and seedling growth are reviewed here under.

Ramana *et al.*, (2002) reported that the distillery effluent did not show any inhibitory effect on seed germination at low concentration except in tomato, but in onion the germination was significantly higher (84%) at 10% concentration as against 63% in control. Irrespective of the crop species at highest concentrations (75% and 100%), complete failure of germination was observed. The speed of germination, peak value and germination value also followed a similar trend. They found that concentration of 5% was critical for seed germination in tomato and bottle gourd and 25% in the rest of the crops. Based on the tolerance to distillery effluent, the crops studied have been arranged in the following order: cucumber > chilli > onion > bottle gourd > tomato.

Chandra *et al.* (2004) reported that irrigation of the pots by 1-10% distillery effluent (anaerobically treated) stimulated the growth of the soil microflora (increased number of bacteria, fungi and actinomycetes) and *Phaseolus aureus* plants (increased shoot and root lengths, biomass, chlorophyll and protein contents). Further, 15-20% distillery effluent had toxic effect on soil micro flora as indicated by reduced number of bacteria, fungi and actinomycetes. Reduction in shoot, root lengths, biomass, chlorophyll and protein content of *Phaseolus aureus* was also observed when irrigated by 15-20% treated distillery effluent.

Kamlesh *et al.* (2007) studied the per cent reduction in seed germination with various concentrations of distillery and sugar factory treated combined effluent. Wheat, barely, garden pea and black gram showed no reduction in germination at lower

concentration of effluent (25%) in comparison to control. Mustard showed highly significant reduction in germination even at lowest concentration of the effluent mixture. The inhibition in 75% and 100% treated effluent concentration was highly significant in all the seeds of different plant species.

Sandeep *et al.* (2007) studied the effect of various concentrations of treated distillery effluent (*viz.* 0%, 25%, 50%, 75% & 100%) on seeds germination, speed of germination, peak value and germination value of three selected crops *i.e.* wheat (*Triticum aestivum*), pea (*Pisum sativum*) and lady's finger (*Abelmoschus esculentus*). Germination per centage decreased with increase in concentration of effluent in all the tested seeds, where as the germination speed, peak value and germination value increased from control to 25% and 50% concentration and decreased from 50% to 75% and 100% effluent.

The slight and gradual reduction in plumule and radicle length and number of lateral roots from lower to higher concentrations of distillery and sugar factory treated combined effluent on seedlings of different plant species was recorded. In barley, the plumule length and number of lateral roots significantly increased in 25% and 50% concentrations of effluent mixture while decreased in 75% and 100% concentrations of the effluent mixture in comparison to control. Growth inhibitory effect in wheat, garden pea, black gram and mustard were invariably observed in all the concentration levels of effluent mixture when compared with the control (Kamlesh *et al.*, 2007).

Pandey *et al.* (2008a) reported that undiluted (100%) effluent produced significant inhibition in seed germination and seedling growth parameters (length of radicle and plumule and fresh and dry weight) in both maize and rice. However, less severe, the inhibitory effect of the 1:1 diluted (50%) effluent was also significant.

Gahlot *et al.* (2011) studied the effect of digested spentwash on the seed germination of chickpea and showed that lower concentrations (2.5 to 20%) of digested spentwash did not inhibit seed germination under laboratory conditions. But in pot experiment, 100 % germination was recorded with digested spentwash irrigation up to 20%, but the seeds failed to germinate at a higher concentration (50%) of digested spentwash, when soil was amended with different concentrations of digested spentwash at the pre-sowing stage, seed germination was observed up to a digested spentwash concentration of 250 m³ ha⁻¹. The lowest concentration (2.5%) of digested spentwash did not inhibit nodulation, root and shoot weight of chickpea. In case of soil amendment, there was no adverse effect on nodulation, root and shoot weight up to 100 m³ ha⁻¹ of digested spentwash.

Piyush Malaviya and Anuradha Sharma (2011) showed the effect of various concentrations of distillery effluent on siliqua quantity of *Brassica napus* at regular time intervals. The number of siliqua per plant was found to be maximum in E20 (20% effluent) and minimum in E100 (100% effluent). This indicates that there was an increase in siliqua production from control (E0) to E20 (20% effluent) and then there was a decrease with further increase in effluent concentration. It has also been observed that

there was a delay in siliqua development in E60 (60% effluent), E80 (80% effluent), and E100 (100% effluent) during early periods (i.e. 40th and 45th day) of siliqua formation, whereas in treatment E20, siliqua formation started from 40th day of sowing.

Rath *et al.* (2011) reported that the growth and chlorophyll content of the sugarcane in different treatments showed an increasing trend over the control. Average height of the sugarcane plant, length of leaves and breadth of the leaves of the test crop after 210 days showed an increase of 13.45% in 50% DSW treated plot over the control. However, the growth showed negative trend in 100% DSW. Similarly the average girth of the stem, average number of leaves per plant, average number of tillers per plant, average leaf area index and chlorophyll content of the test crop after 210 days of planting showed an increase of 16.79%, 21.18%, 57.5%, 62.84% and 28.99%, respectively in 50% DSW treated plants over control and a negative trend in 100% DSW.

Chandrabu *et al.* (2011) reported that the sprouting and growth of gardenia plant leaves, uptake of all the parameters were very good in both 1:2 and 1:3 dilution of distillery spentwash as compared to 1:1 SW and raw water. In 1:1, 1:2 and 1:3 spentwash irrigation, the uptake of nutrients such as fat, calcium, zinc, copper and vitamins. Carotene and vitamin 'C' were almost similar but the uptake of the nutrients and parameters such as protein, fiber, carbohydrate, energy, magnesium and phosphorus were much more in the case of 1:1 and 1:2 spentwash irrigation than in 1:3 and raw water irrigation.

The germination per cent in *P. sativum* was 82.22% at 25 per cent concentration. The vigor index of tested vegetation also varied with respect to different concentration of effluent, the highest vigor index, root and shoot length of the seedlings were recorded at 25% concentration whereas at 75% of effluent concentration decrease in vigor index, length of root and shoot were recorded (Kamini *et al.*, 2012).

Anuradha Mehta and Nagendra Bhardwaj (2012) observed that untreated effluent produced significant inhibition in seed germination and seedling growth parameters – length of root, length of shoot, number of lateral roots and dry weight of seedling in both *Vigna* and *Cicer* under laboratory condition. Seeds of *Vigna* showed enhanced germination per centage (66.60%) in treated effluent as compared to untreated effluent (43.33%).

Ray *et al.* (2012) reported that mix of fly- ash and diluted distillery effluent (E2) has a potential for improving *Calendula officinalis* plant growth. Shoot length has increased by 92.3% in E2 (Ordinary garden mud + fly ash with diluted distillery effluent) and 65.0% in E1 (Ordinary garden mud + diluted distillery effluent) as compared to the control (Ordinary garden mud + water). The root length in E2 was 71.3% and in E1 53.2% more than the control. Similarly the number of branches in E2 was 733.3% and in E1 166.7% more than the control. The number of leaves was 247.3% and 154.5% more in E2 and E1, respectively. Similarly, the number of flowers was 600% more in E2 and 50% more in E1 than the control.

Bhupinder Singh and Anoop Yadav (2012) studied the effect of different concentrations of distillery effluent (0, 6.25, 12.5, 25, 50, 75 and 100%) on seed germination (%), vigor index (VI), plant shoot length and root length of three different cultivars of wheat. The maximum phytotoxicity on germination per centage (65%, 60% and 60%) was observed at 100% effluent concentration in different wheat cultivars i.e. WH-147, PBW-343 and PBW-373, respectively. The distillery effluent did not show any inhibitory effect on seed germination, vigor index, shoot length and root length at low concentration in all the three wheat cultivars.

Rath *et al.* (2013) observed the highest germination per centage at 15% concentration of distillery spentwash. In 15% concentration, germination index was highest (16.66) on the 3rd day while it was lowest (6.42) on 7th day at 50% DSW treated seeds. The seed vigour index gradually increased from 3rd day to 7th day in all treatments. It was highest (2030) at 15% DSW treated seeds on 7th day and lowest (446.4) in 50% DSW concentration on the 3rd day. The highest seedling root length (12.62 cm) and shoot length (7.68 cm) of rice seedlings were recorded at 15% and 20% distillery spentwash and lowest root length (3.10 cm) and shoot length (1.86 cm) were recorded on the 3rd day at 50% concentration of DSW.

Parvathi *et al.* (2014) studied the effect of distillery effluent on germination and biochemical parameters of chickpea. Highest percentage of germination was observed in 25% effluent concentration. Root and shoot length, fresh and dry weight, vigour index and tolerance index were highest in 25% effluent concentration and it was significantly reduced in higher effluent concentrations (50%, 75% and 100%) when compared to control.

Adhikary (2014) revealed that different concentrations of effluent in soil (5%, 10%, 25%, 50% and 75%) enhanced different growth parameters (shoot length and weight & root length and weight) over control in 25 days old tomato plants. Shoot length (48%) of tomato plant was highest in 25 % effluent treatment followed by 50 %, 10 %, 75 % and 5 % treatment and their values were 33 %, 26 %, 19 % and 10 %, respectively. The 100 % effluent treated plants showed a decreased trend of shoot length (13 % over control). Similar trends were observed in shoot fresh and dry weight and root length due to 25 % effluent treated soil.

Shyam Veer Singh and Swami (2014) studied the toxicity of distillery effluent (DE) using seeds of moong (*Vigna radiata*), guar (*Cyamopsis tetragonoloba*), Makai (*Zea mays*) and gehu (*Triticum aestivum.*) Seed germination, root length, shoot length, root weight, shoot weight and chlorophyll level of all the crops were decreased with increase in the effluent concentration. Results suggested that 40% DE is suitable for germination of plants: *C. Tetragonoloba* (67.7%), *T. aestivum* (64%) and *Z. Mays* (92.3%) except in *V.radiata* (98% germination with 60% DE). The high DE (80 and 100%) indicates a toxic impact on seed germination. The better seedling growth and biomass were also showed in 20 – 60 % DE in all plant species.

2.3. Effect of foliar application of diluted distillery spentwash on growth, yield and quality of crops

The option of soil or foliar application of the distillery spentwash is being suggested for both pollution control and agricultural production. Therefore, distillery spentwash is being used for irrigating horticulture as well as agricultural crops without adversely affecting soil fertility. Different crops are being reported for their difference in tolerance to different dilutions of spentwash. In water scarce situation, spentwash is single permanent water source for irrigation, consequently causes positive effect at lower concentrations on this aspect, studies have been carried out by various researchers (Rani and Srivastava, 1990; Subramani, 1995; Pandey *et al*, 2008a). Adverse effect on the plant and soil has been observed at higher concentrations of the spentwash suggesting that diluted distillery effluent can be used as an alternative to chemical fertilizers because of its high content of N, K, Ca, Mg and S as well as micronutrients and organic matter. The research work on the effect of application of diluted distillery spentwash on crops are reviewed here under.

Devarajan and Oblisamy (1995) recorded higher cane yield of 182.8 tons ha⁻¹ due to irrigation with distillery effluent diluted 50 times. However, cane yield and juice quality decreased with increasing concentration of effluent in irrigation water.

The dry matter yield of maize cultivar African tall was significantly increased by combining FYM, spent slurry and spentwash compost than control (Patil and Shinde, 1995)

Pujar (1995) recorded highest grain yield of wheat at 50 times and maize at 10 times dilution of effluent irrigation. Highest sugar cane yield with 10 times dilution of distillery effluent was obtained along with the pressmud. But the quality parameters in sugar cane were not influenced due to diluted effluent irrigation.

Madhusree (1996) studied the effect of distillery effluent on shoot length, root length and chlorophyll biosynthesis of groundnut and cowpea. Shoot length and root length of both species declined with increasing concentration of effluent. Chlorophyll a and chlorophyll b contents of both species were also reduced at 25% effluent. Chlorophyll b was more severely affected than chlorophyll a. The protochlorophyllide levels decreased in higher concentration of distillery effluent.

Zalawadia *et al.* (1997) noticed that the application of spentwash diluted at any level increased the sugar cane yield. Less diluted spentwash gave a greater yield of biomass than the more diluted ones.

Most of the field crops *viz.*, sugarcane, rice, wheat and mustard showed positive response to biomethanated spentwash application along with irrigation water. Even after the 20th irrigation with spentwash on specific fields, none of the crops showed any toxicity symptoms even up to 30 irrigations. The sugarcane crop receiving nine irrigations followed by ratoon crop receiving five irrigations with 30 per cent

concentration showed better yields as compared to fresh water irrigated crop. The kharif crops like maize and rice responded well to biomethanated spentwash irrigation even up to 40 per cent level. Stress symptoms were visible in case of wheat crop at 40 per cent biomethanated spentwash applied for three years (Joshi, 2002).

Spent wash with different dilution levels *viz.*, 1:5, 1:10, 1:25 or 1:50 were tried. Dilution levels of 1:5 and 1:10 recorded the highest uptake of N, P and K as well as Zn, Cu, Fe & Mn uptake when compared with the undiluted spent wash and control (water without spent wash). The undiluted spent wash resulted in significantly lower nutrient uptake by maize than the control (Sukanya *et al.*, 2002).

Sukanya and Meli (2003) observed that wheat grain yield was significantly increased by dilution level. A grain yield of 50.6 q ha⁻¹ was recorded with irrigation of higher dilution level of 1:50 as compared to other dilution levels but it was found on par with the irrigation with fresh water (51.2 q ha⁻¹). The protein content in grain was the highest in plots with undiluted effluent (13.2 %), which was found on par with lower dilution levels.

Sukanya and Meli (2004) recorded significantly higher maize grain yield of 76.83 q per ha and stover yield of 106.77 q per ha with irrigation by lower dilution of 1:5 as compared to remaining dilution levels and it recorded an increase of 14.72% over grain yield in treatment irrigated with good water. Significantly the lowest grain yield (24.06 q/ha) and stover yield (36.87 q/ha) were recorded due to irrigation by undiluted distillery effluent. Irrigation 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. Quality parameters of maize like highest reducing sugar (1.33%) and protein (11.66 %) contents were recorded in undiluted effluent compared to other treatments and lowest values were observed in the 1:50 dilution (1.18% and 11.01%, respectively).

Pragasam and Dixit (2006) observed the plant height, fresh biomass, tolerance index, phytotoxicity, total free amino acids and proline contents of 15 days old seedlings of *Vigna mungo* treated with different concentrations (10, 25, 50, 75 and 100 per cent) of brewery effluent. All the parameters studied were found to be more in the plants treated with 10, 25, 50 and 75 per cent concentrations of effluent and less than control in those treated with 100 per cent concentration. Maximum values were recorded in the plants treated with 50 per cent concentration and finally suggested that the diluted brewery effluent can be used as liquid fertilizer for better growth of crop plants.

The results of Chandraju and Basavaraju (2007) and Chandraju *et al.* (2008) showed that the diluted spentwash increased the uptake of nutrients, plant height, growth and yield of leafy vegetables, nutrient content of cabbage and mint leaf (Chandraju *et al.*, 2008a), top vegetables (Chandraju *et al.*, 2008), pulses, condiments and root vegetables (Chandraju *et al.*, 2008b, Chandraju *et al.*, 2008c). Banu Lekha (2007) and Latha (2008) concluded that repeated application of biomethanated distillery spentwash at 37.5 m³ ha⁻¹

registered the highest growth attributes, annual and total production of green biomass and quality of the Cumbu Napier hybrid fodder.

Kamlesh (2007) revealed that total chlorophyll contents and amylase activity were found to decrease from lower to higher concentration of distillery and sugar factory mixed effluent in wheat, barley, garden pea, and black gram. In case of barley both chlorophyll contents and amylase activity increased in 25% and 50% concentrations of combined effluent treatments. They showed decrease in 75% and 100% concentration of effluent mixture in comparison to control, but the reduction was higher than control in 75% concentration of effluent mixture. The total chlorophyll contents and amylase activity were significantly altered in barley in all the treatments.

Chandrabu *et al.* (2008) studied the changes in nutritive value of coriander, spearmint and fenugreek/methi with application of raw water and application of 33% primary treated distillery spentwash (PTDS). The application of 33% PTDS recorded maximum protein, fat, fibre and carbohydrates, along with major, secondary and micronutrients than raw water in all medicinal plants.

Chidankumar *et al.* (2009) studied the irrigation with distillery spentwash of different proportions on top vegetables. The yields were very high in the case of 33 % spentwash irrigation for all types of vegetables and moderate in 50%, while very poor in raw water. However, the per centage yield was maximum in the case of ridge gourd (140.7%) and minimum in the case of bottle gourd (42.8%), snake gourd (86.7%), bitter gourd (55.6 %), pumpkin (52.3 %) and ash gourd (48.0 %).

Chidankumar *et al.* (2010) studied the effect of distillery spentwash irrigation in normal and spentwash treated soil on pulse production. All pulse plants were highly responsive and higher yield in the case of irrigation with 33% SW as compared to RW. The use of spentwash for irrigation enriches the soil fertility without any adverse effect and hence spentwash (33%) can be conveniently used for the irrigation of pulses without external fertilizers (either organic or inorganic).

Gahlot *et al.* (2011) studied the effect of digested spentwash on nutrient uptake by chickpea and reported that soil amendment with digested spentwash at the pre-sowing stage resulted in increased nutrient (N and P) uptake up to a concentration of 50 m³ ha⁻¹, after which there was decrease in nutrient uptake. The nitrogen uptake was 18.7, 22.4 and 27.4 mg plant⁻¹ in soil amended with 10, 25 and 50 m³ ha⁻¹ of digested spentwash, respectively. The corresponding values for the P uptake of chickpea plants were 0.88, 1.01 and 1.21 mg plant⁻¹. The lowest nutrient uptake of N (11.8 mg plant⁻¹) and P (0.68 mg plant⁻¹) in chickpea was observed at the 250 m³ ha⁻¹ concentration. The highest chlorophyll *a* fluorescence of cowpea was found at the 10% concentration of digested spentwash, while a slight decrease in chlorophyll *a* fluorescence was observed when the plants were irrigated with 20% digested spentwash. When the soil was amended at the pre-sowing stage, highest chlorophyll *a* fluorescence was observed at 100 m³ha⁻¹ of digested spentwash. At the 250 m³ha⁻¹ concentration, a slight decline in chlorophyll *a* fluorescence was observed.

Radha Jain and Srivastava (2012) studied the different rates of crude spentwash (5, 10, 20 and 100 ml kg⁻¹ soil) along with digested spentwash (100 ml kg⁻¹ soil) showed improvement in bud sprouting (10.5 %), settling height (40 %), root number (9.4 %), root length (13.2 %), chlorophyll a (52.9 %) and b (55.3 %) contents and activity of catalase (98 %) enzyme of sugarcane over control at low rate of crude spentwash (5 ml kg⁻¹ soil). Whereas, higher doses of spentwash (20 and 100 ml kg⁻¹ soil) decreased these parameters markedly except peroxidase which was found higher at all the levels of both CSW and DSW.

Ray *et al.* (2012) reported that chlorophyll a and chlorophyll b content of *Calendula officinalis* ornamental plant were 21.7% and 31.4%, respectively more in E2 (ordinary garden mud + fly ash with diluted distillery effluent) and 14.2% and 16.7% more in E1 (ordinary garden mud + diluted distillery effluent) than the control (ordinary garden mud + water).

Sachin *et al.* (2012) reported that the plant height/plant, root length/ plant, number of leaves/plant, number of flowers/plant, number of fruits/plant and fruit length/plant, fruit diameter/plant, fruit weight/plant and crop yield of egg plant were found maximum at 50% concentration of distillery effluent as compared to control. The lower concentration of distillery effluent showed better performance on flowering and fruiting stage of the egg plant.

Vinod Kumar and Chopra (2013) revealed that the high yield of *Vigna radiata* (Mung bean; Var. Pusa-105), was subjected to fertigation with distillery effluent (DE) in rainy and summer seasons. At 45 days after sowing, the highest shoot length (68.5cm), root length (29.3cm), dry weight (18.3g), chlorophyll content (4.73 mg./g.f.wt) and LAI/plant (4.68) of *V. radiata* were recorded with 50% concentration of DE in the rainy season, while in the summer season, it was recorded with 25% concentration of DE (62.6 cm, 26.1cm, 16.5g, 3.95mg./g.f.wt and 4.36 of shoot length, root length, dry weight, chlorophyll content and LAI/plant, respectively).

Rath (2013) reported that the chlorophyll content of seedlings was highest in 15% concentration of DSW and gradually decreased with increase in concentration. The chlorophyll content was highest (0.712 mg ml⁻¹) on the 7th day at 15% concentration and lowest (0.353 mg ml⁻¹) on the 3rd day in control. The amount of carotenoid was maximum in 20% DSW concentration on 7th day after treatment (0.008 mg g⁻¹fresh wt.) and minimum in 50% DSW concentration on 3rd day.

Parvathi *et al.* (2014) studied the effect of distillery effluent on chlorophyll content of chickpea. Maximum chlorophyll content was observed in 25% effluent concentration and it was found to be reduced as the concentration of the effluent increased (50%, 75% and 100%) when compared to control.

2.4. Effect of foliar application of nutrients on growth, yield and quality of crops

Foliar application of various macro and micro nutrients has been proved beneficial, foliar feeding is a relatively new and controversial technique of applying liquid fertilizer directly to leaves. Foliar fertilizers that contain various macro and micro nutrients are being used in vegetable and fruit crops. Foliar fertilizers are known to immediately deliver nutrients to the tissues and organs of the crop for better crop growth and crop productivity and also helps in uptake of major nutrients. The research work on the effect of foliar application of nutrients on growth, yield and quality of crops are reviewed here under.

Ravi Nandan *et al.* (1998) reported that foliar application of 2 per cent urea at flowering increased the grain yield of chickpea by 22.9 per cent over control.

Sajida Perveen and Hafeez Ur Rehman (2000) studied the effect of foliar application of zinc, manganese and boron alone and in combinations applied to sweet orange. The highest yield of 105.3 kg/tree was obtained from trees sprayed with Zn alone and also increased the leaf Zn content. Application of Mn significantly increased the leaf Mn content and fruit yield and intensified the red colour of skin and juice. Application of B significantly increased the fruit yield but did not influence the leaf boron content.

Chaurasia *et al.* (2005) reported that application of 5 foliar sprays of water soluble fertilizers significantly increased growth, yield and quality of tomato. Maximum plant height (125.4 cm), number of branches (4.2), fruit length (4.90 cm), fruit diameter (4.51 cm) and number of fruits per plant (24.6) were found in the treatments with foliar sprays of water soluble formulation of NPK 19:09:19, sprayed 5 times followed by 5 foliar sprays of 19:19:19. However, the average fruit weight of 81.6 g was recorded in the 5 foliar sprays of multi K. The maximum T.S.S. content was noted in NPK at the ratio of 17:10:27. The minimum values in all the parameters were recorded in the control having only recommended dose of fertilizer.

Thalooth *et al.* (2006) studied the effect of foliar application of zinc (300 ppm Zn-EDTA), potassium (2.0% KNO₃) and magnesium (50 ppm MgSO₄) on growth, yield and yield components of mungbean plants grown under water stress conditions. Foliar application of Zn-EDTA significantly increased the growth parameters (plant height, number of branches, leaf area) and yield characters (number of pods, number of seeds, seed yield and straw yield) compared to control and foliar application of potassium had the greatest stimulatory effect on growth and yield parameters of mungbean.

Yildirim *et al.* (2007) reported that foliar application of urea increased the head weight, head diameter, plant weight and plant height of both broccoli cultivars AG 3317 and AG 3324 in all the years of experiment (2003, 2004 and 2006 respectively). Head and leaf dry matter contents of both cultivars were negatively affected by mineral nitrogen treatment and foliar urea applications. 1.0% urea application decreased significantly ($P < 0.05$) the head dry matter content, compared to the other treatments. The SPAD chlorophyll meter values were increased with increasing urea concentration

for both cultivars but vitamin C content was decreased with increasing the urea concentration.

Basavarajeshwari *et al.* (2008) studied the effect of foliar application of micronutrients on growth and yield of tomato (Megha). The foliar application of boric acid @ 100 ppm resulted in maximum number of primary branches (18.30), yield per plant (2.07kg) and fruit yield (30.50 t/ha), followed by the mixture of micronutrients (B, Zn, Mn and Fe @ 100 ppm and Mo @ 50 ppm) recording fruit yield of 27.98 t/ha and differed significantly from the control. The maximum cost benefit ratio of 1.80 was obtained with application of boron recording Rs 97,850 /ha of net returns followed by mixture of micronutrients (1.74) recording Rs 88,900 /ha net returns compared to control (1.40) which recorded minimum net returns of Rs 53,250 /ha.

Baloch *et al.* (2008) studied the effect of foliar application of different concentration of higrow (combination of macro and micro nutrients) on growth and yield of chilli. Higrow at 8 ml/L of water resulted in 68 cm plant height, 6.93 branches plant⁻¹, 118.86 fruits plant⁻¹, 4.19 cm fruit length, 395 g fresh chilli fruit weight plant⁻¹ and 14977 kg fresh chilli yield ha⁻¹; while decreasing concentration to 7 ml/L of water produced 67.86 cm plant height, 6.53 branches plant⁻¹, 117.20 fruits plant⁻¹, 4.14 cm fruit length, 391.33 g fresh chilli weight plant⁻¹ and 14562.33 kg fresh chilli yield ha⁻¹. Further reduction in higrow concentration to 6 ml/L, 5 ml/L and 4 ml/L water caused significant and negative effect on all the growth and yield components of chilli. However, the control plots produced 63.46 cm plant height, 4.20 branches plant⁻¹, 93.06 fruits plant⁻¹, 2.87 cm fruit length, 388.33 g fresh chillies weight plant⁻¹ and 10525.00 kg fresh chilli yield ha⁻¹ which were significantly lesser than foliar fed plots.

Potarzycki and Grzebisz (2009) reported that the maize crop responded significantly to zinc foliar application in two of three years. The optimal rate of zinc foliar spray for achieving significant grain yield response was in the range of 1.0 to 1.5 kg Zn/ha. Grain yield increase was 18% (mean of three years) as compared to the treatment fertilized only with NPK. Plants fertilized with 1.0 kg Zn/ha significantly increased both total N uptake and grain yield.

Singandhupe *et al.* (2010) studied the effect of distillery effluents from sugar industries on sugarcane growth, yield and juice quality. Application of nutrient enriched distillery effluents without dilution affected plant growth parameters such as plant height (2.5 m), number of leaves/cane (5.3), number of tillers/hill (4.3) at harvest; yield (42.7 tonnes/ha) and quality of cane juice (pH 5.6, EC 10.6 dS/m, specific gravity 1.096 g/cm³, Brix 21.1%, Polarity 17.2%) at significant level, but improved these parameters when combined with freshwater at various levels. Alternate application of distillery effluent and freshwater gave the highest cane yield (133.8 tonne/ha) and sugar yield (18.5 tonnes/ha).

Salam *et al.* (2010) reported the highest pulp weight (88.14%), dry matter content (5.34%), TSS (4.50%), acidity (0.47%), ascorbic acid (10.95 mg/100g), lycopene content (112.00 µg/100g), chlorophyll-a (41.00µg/100g), chlorophyll-b (56.00 µg/100g),

marketable fruits at 30 days after storage (67.48%) and shelf life (16 days) of tomato were recorded with the combination of 2.5 kg B+ 6 kg Zn/ha and recommended dose of NPK fertilizers (N= 253, P= 90, and K= 125 kg/ha).

Mahnaz *et al.* (2010) studied the interaction of paclobutrazol (0 and 100 mg l⁻¹), boric acid (0, 150 and 300 mg l⁻¹) and zinc sulfate (0, 100 and 200 mg l⁻¹) on reducing vegetative growth and increasing yield and fruit quality of Selva strawberry. Foliar application of ZnSO₄ increased the leaf number, leaf area, length and diameter of petiole, fresh and dry shoot root ratio, yield, total soluble solid, acidity and vitamin 'C'. However, combined PP 333 × B decreased total soluble solid in fruits.

Muhammad *et al.* (2010) revealed that foliar application of Zn and B significantly influenced the days to flowering, fruit yield tree⁻¹, % dieback, % chlorosis and % rosette plant⁻¹, whereas days to fruit set, % fruit set and % fruit drop of orange were not significantly affected by foliar spray of Zn and B alone. The maximum fruit yield plant⁻¹ was obtained when high concentration of zinc (1.0 %) with low concentration of boron (0.02 %) applied to the plants. The maximum days to flowering were obtained with foliar Zn application. The low conc. of Zn (0.5%) in combination with high conc. of B (0.04%) positively reduced the % dieback, % chlorosis and % rosette tree⁻¹.

Saira *et al.* (2011) reported that highest plant height, number of branches per plant, length of branches per plant, number of leaves per plant, leaf area, stock length, days to first flower emergence, flower diameter and flower quality were recorded in the treatment receiving Zn, B, Fe, Mn (5000±200mg/100ml) as compared to control. Foliar fertilization influenced the days to first flower emergence as compared to control where there was no foliar spray of macro and micro nutrients.

Hasina *et al.* (2011) studied the effect of foliar application of nitrogen (N), potassium (K) and zinc (Zn) solutions on the growth of wheat. Maximum emergence m⁻² (309), number of tillers (527) m⁻², plant height (100.50cm) and number of spikes (238) m⁻² were recorded in those plots which were sprayed with 0.5% N, 0.5% K and 0.5% Zn solutions two times while minimum emergence m⁻² (130), number of tillers (263) m⁻², plant height (75.25cm) were recorded in control plots and minimum number of spikes (123)m⁻² were recorded in plots sprayed with 0.5% K solution two times. It was concluded that growth performance of wheat was highly influenced by the application of two times spray of 0.5 % N, 0.5% K and 0.5% Zn solutions.

Khalifa *et al.* (2011) reported that the foliar spraying of zinc sulphate (1.5, 3.0 and 4.5 g/l) or boric acid (5 , 10 and 20 ppm) at all the rates and combinations significantly increased growth parameters of iris plant (ornamental plant) such as flower characteristics and bulblet number and yield/plant as compared with the control treatment. The treatments also significantly increased the leaf carbohydrate, pigment, nutrients *i.e.* N, P, K, Fe, Mn, Zn and B content, as well as carbohydrate and oil content of flowers (%) and its nutrients content as compared with the control. The most promising results were obtained from plants treated with Zn at 4.5g/l combined with 20 ppm B.

Mohammad Azeem and Rafiq Ahmad (2011) reported that significant improvement was observed in the number of fruits, circumference and weight of fruits, chlorophyll and protein contents of tomato leaves due to the foliar application of combined treatment (K+Fe+B) under both non saline and saline conditions. Lowest number of fruits, circumference and weight of fruits, chlorophyll and protein contents of tomato leaves were recorded with foliar application of potassium, iron and boron alone.

Mohammad Reza Asgharipour and Hamid Reza Azizmoghaddam (2012) studied the effect of foliar micro-nutrients spraying on growth parameters, yield and yield attributes of foxtail millet. The combination of Mn and Zn in a foliar spray contributed to a greater plant growth compared to the other spray treatment. The greatest growth parameters (height: 84.00 ± 6.14 cm, collar diameter: 5.20 ± 0.32 cm and panicle length: 8.53 ± 0.70) were obtained with a Mn and Zn foliar spray, whereas the lowest (height: 74.08 ± 2.57 cm, collar diameter: 4.71 ± 0.15 cm and panicle length: 7.30 ± 0.30) growth parameters were obtained with the control (tap water spraying). Mn and Zn foliar spray increased the panicle number per plant and the grain number per panicle of millet by 5.1 and 4.5, respectively over the control.

Abdur Rab and Ihsan-ul Haq (2012) reported that foliar application of borax alone significantly enhanced the number of branches per plant, number of flowers per cluster, fruits per cluster, fruits per plant, fruit weight, fruit firmness and total soluble solid content of the tomato fruits

Hythum *et al.* (2012) revealed that micronutrient fertilization using Zn + Mn + Fe treatment was the most effective treatment for improving maize growth and yield. Foliar spraying of micronutrients gave the highest values of ears/plant, grains/ear, 100-grain weight and grain yield in 1st and 2nd seasons.

Shilpa Mohan Shitole and Dhupal (2012) revealed that foliar application of micronutrients solutions of CuSO₄, FeSO₄, ZnSO₄ (500, 1000, 1500 mg/l) and commercial micronutrient mixture Miczink (0.50, 0.75, 1 ml/l) increased the photosynthetic pigments like chlorophyll a, chlorophyll b, proteins and phenols of *Cassia angustifolia*. Among the different treatments of micronutrients FeSO₄, ZnSO₄ (1500 mg/l) and Miczink (1ml/l), had shown maximum positive influence on total chlorophyll contents in *C. angustifolia*. While for enhancing phenol contents in leaves, CuSO₄ (1000 and 1500 mg/l) emerged best treatment over control.

Arvind *et al.* (2012) studied the pre-harvest foliar spray of nutrients CaCl₂ @1.2%, Borax@0.5%, K₂SO₄@ 0.5%, Ca(NO₃)₂@1.0%, ZnSO₄@0.5%, ZnCl₂ @0.3% on mango. The results showed that the trees sprayed with 0.5% borax recorded maximum fruit yield, fruit weight, fruit volume, T.S.S., reducing sugar, non reducing sugar and ascorbic acid content, However, this treatment was found to be at par with 1% Ca(NO₃)₂. With regard to maintenance of post harvest fruit quality in mango, the minimum physiological loss in weight was reported in 1.0% Ca(NO₃)₂ followed by CaCl₂ (1.2%) up to the end of 12th day. Other quality parameters like fruit TSS, sugar and ascorbic acid content were best maintained by borax, calcium and potassium treatments.

Majid *et al.* (2012) revealed that foliar application of boron and zinc recorded more number of spikes per plant, grains per spike, grains per square meter, harvest index (HI) and grain yield (kg/ha) of wheat but had no effect on thousand grain weight. The number of spikes per plant, grains per square meter and grain yield increased with raise in the doses of foliar application, so that highest of these were noticed in dose of 2 lit/ha than 1lit/ha.

Haq *et al.* (2012) studied the interactive effects of nitrogen (N), phosphorus (P) and zinc (Zn) on growth and yield of tomato. The various growth and yield parameters showed that early flowering was observed when plots received phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. In contrast, flowering was significantly delayed when plots received nitrogen alone at 200 kg/ha. The minimum disease incidence (3.67%) was recorded in plots applied with phosphorus at 100 kg/ha and zinc at 10 ppm without nitrogen. Maximum number of fruits per plant (41.67) was observed when plots received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm. Total yield (28.43 t/ha) was increased by 100% as compared to control (13.44 t/ha) when plots received nitrogen at 150 kg/ha, phosphorus at 100 kg/ha and zinc at 10 ppm.

Olga *et al.* (2013) revealed that foliar application of N has improved spring wheat grain yield and foliar N fertilization in wheat was improved quality specifically increased protein content in grain and protein yield.

Sajid *et al.* (2013) studied the foliar application of macro and micro nutrients with different concentration levels on the vegetative growth, flowering and yield of tomato, foliar application of nitrogen at the rate of 5.5 g/100 ml + boron 5 g/100ml + zinc 5 g/ml recorded significantly higher plant height (cm), number of leaves plant⁻¹, leaf length (cm), days to flowering, number of flower clusters plant⁻¹, fruit set percentage, small fruits plant⁻¹, medium fruits plant⁻¹, large fruits plant⁻¹, length and width of fruit (cm), fruit weight (g), fruit yield plant⁻¹ (kg), yield plot⁻¹ (kg), and yield hectare⁻¹ compared to control.

Dubey *et al.* (2013) studied the effect of foliar application of micronutrient on growth and yield of bell pepper. Plant height, primary branches, days to 50% flowering, fruit size and fruit yield were significantly increased with the foliar application of borax @ 0.5% followed by mixture of zinc sulphate, borax, copper sulphate and manganese sulphate and lowest growth and yield was recorded in control.

Mosavifeyzabadi *et al.* (2013) studied the effect of nitrogen and zinc spray on yield and yield components of corn under drought stress. Drought stress significantly affected the stem and ear diameter, ear length, chlorophyll value, leaf area index, leaf relative water content of stem, ear and leaves, dry weight, number grains in ear and row, number of rows in ear, unfilled seed per centage and thousand grains weight. Nitrogen increased the seed yield and yield component except thousand grains weight and the number of rows in a ear. Foliar application of Zn increased the grain yield, thousand grains weight and number grains per ear (16.5, 9 and 5.5%, respectively) as compared to control

The highest protein content (12.82%), maximum moisture content (10.9%), maximum crop growth rate and absolute growth rate were recorded when the wheat crop was fertilized with T8 [Nitrogen @ 60 kg ha⁻¹ at sowing + 40 kg ha⁻¹ at tillering + 10 kg ha⁻¹ at anthesis (spray) + 10 kg ha⁻¹ after anthesis (spray)] + Sulfur @ 15 kg ha⁻¹ at sowing + 10 kg ha⁻¹ at anthesis (spray) + 5 kg ha⁻¹ after anthesis (spray) as compared to control (Beena *et al*, 2013).

Naga Sivaiah *et al.* (2013) studied the effect of foliar application of boron, zinc, molybdenum, copper, iron, manganese, mixture of all on two varieties of tomato *viz.*, UtkalKumari and Utkal Raja. In tomato cv. UtkalKumari, maximum growth rate (85.7 %) was observed with foliar application of zinc followed by application of micronutrients mixture (78.2 %) and boron (77.5 %). In tomato cv. Utkal Raja, increase in the number of branches per plant was observed with the application of manganese (148.7 %) followed by micronutrient combination (144.1 %). In Utkal Kumari, the fruit yield per plant ranged from 1.336 to 1.867 kg and in Utkal Raja, it ranged from 1.500 to 1.967 kg/plant. In both the varieties, combined application of micronutrients produced the maximum fruit yield followed by application of boron and zinc.

Rahim *et al.* (2013) reported that the foliar application of boron and zinc combination significantly increased berry (number, length and weight), cluster (length and weight) and seed characteristics (number and size) and TSS. Based on results, the most fruit set index (berry number per cluster) was observed in Turkmenistan No.7, 4 and 3 grape cultivar respectively, although it was not significant among cultivars. Also effect of different cultivars were different significantly on chemical (TSS and pH) and physical (berry length and weight, cluster length and weight and seed number and size) characters. Generally, different cultivars responded differently to application of B and Zn.

Amjad *et al.* (2014) reported that maximum fruit length, diameter and yield were noticed in foliar application of micronutrients (Zn + Cu + Fe + Mn + B). The juice pH decreased and the juice acidity increased in a linear fashion after foliar spray of micronutrients. The total soluble solids of fresh fruit juice ranged between 7.01% to 8.88% and vitamin 'C' ranged from 4.80% to 7.90% after foliar spray. So the foliar spray of micronutrients significantly ($P \leq 0.05$) affected the quality of peach fruit.

Veselinka *et al.* (2014) studied the effect of foliar application of nitrogen at flowering and milk stage of wheat and recorded increased grain yield, protein content and bread weight as compared to control.

Saravaiya *et al.* (2014) reported that significantly higher plant height (132.77 cm), number of branches plant⁻¹ (5.96), fresh weight of plants (25.70 t ha⁻¹), dry matter yield of plants (7669.04 kg ha⁻¹), maximum days to last picking (166.01), number of fruits plant⁻¹ (34.43), fruit length (5.47 cm), fruit diameter (4.57 cm), fruit volume (65.94 cm³), single fruit weight (49.00 g), fruit weight plant⁻¹ (1.69 kg), number of locules fruit⁻¹ (3.01), pericarp thickness (6.27 mm), fruit yield plot⁻¹ (70.86 kg), fruit yield ha⁻¹ (46.87 t.) and marketable fruit yield ha⁻¹ (45.68 t) were recorded in the treatment receiving RDF

+ mixture of all micronutrients and lowest growth and yield parameters were recorded in control.

Sandhya Rani and Patro (2014) studied the effect of bio-fortification of zinc on the grain yield and grain zinc content in finger millet. Zinc application through soil as well as foliar spray was comparatively studied in finger millet. The soil application of ZnSO_4 @ 12.5 kg ha^{-1} at the time of sowing enhanced the grain yield by 13.3%, grain zinc content by 8.95%, while foliar spray of ZnSO_4 @ 0.5% increased the grain zinc content by 10.2% and not the grain yield.

Harris and Mathuma (2015) studied the foliar application of boron, zinc and their combinations on growth and yield of tomato cv. Thilina. Foliar application of Zn alone at 250 ppm resulted in the maximum plant height, total dry weight, number and fresh weight of fruits/ plant. Foliar application of B at 250 ppm increased the dry weight of leaves/ plant and dry weight of stem/ plant and dry weight of roots/plant were high in both B at 250 ppm and Zn at 150 ppm. In all parameters, the lowest performance was recorded in the control.

2.5. Effect of application of distillery spentwash on soil properties

The utilization of distillery spentwash in agricultural fields creates organic fertilization in the soil because spentwash contains high amount of organic matter, which increases the availability of certain nutrients and also improves the physical condition of soil. Availability of nutrients plays an important role in increasing the yield and quality of crops. Though it is considered as wastewater, scientific use can help in providing valuable nutrients to crops. Some of the reviews on these aspects are covered below:

2.5.1 Effect on soil physical properties

Mbagwu and Ekwealor (1990) reported 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 holding capacity of soil (14.7 to 18.3 %).

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

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

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

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

Vinod Kumar and Chopra (2013) studied the effect of application of diluted distillery effluent on soil moisture, water holding capacity and bulk density of soil. The maximum physical parameters were observed with the application of 5% dilution of distillery effluent and minimum was recorded with the 100% concentration of effluent in rainy and summer seasons.

Adhikary (2014) reported that the physiochemical parameters of soil after harvest of tomato crop at different per centage dilution of sugar industry effluent were increased BD, OC, CO_3 , HCO_3^- , Total PO_4^{-3} , Total NO_3^{-2} , Total K^+ , Mg^{2+} , CaSO_4^{-2} , Cl^- and decreased pH, Soil Moisture and WHC over control soil.

2.5.2 Effect on soil chemical properties

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

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

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

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

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

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

Zalawadia *et al.* (1997) studied the effect of irrigation with tube well water (S₀) as well as with spentwash diluted 25 (S₂₅), 50 (S₅₀) and 100 (S₁₀₀) times on yield and nutrient uptake by sugarcane grown on typical chromustert. The post harvest nutrient status of soil revealed that there was significant increase in soil organic carbon, available N, P, S, Fe, Mn, Cu & Ni over control. While the exchangeable Na, Ca and Mg significantly decreased with increase in proportion of spentwash in irrigation water, but Pb and Cd remained unaffected due to spentwash treatments.

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

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

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

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

Sukanya and Meli (2004) reported that the highest available NPK contents were recorded in the treatment receiving undiluted spentwash followed by 1:5 dilution and lowest was recorded in the control (water). But in case of total nutrient uptake highest was observed with the application of 1:5 dilution spentwash and lowest was recorded in the undiluted distillery spentwash.

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

A field experiment was conducted to study the effect of ferti-irrigation of spentwash on sugarcane crop and on soil properties. It was found that chemical properties of soil did not differ significantly due to ferti-irrigation of distillery spentwash except organic carbon, available potassium and iron. Ferti-irrigation of distillery spentwash at 150 per cent RDN recorded higher OC, available K and Fe after the harvest of crop (Suma, 2006).

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

Gahlot *et al.* (2011) studied the effect of applying digested spentwash along with irrigation or as soil amendment on various soil properties. With increasing amounts of digested spentwash in the irrigation water, there was an increase in pH of the soil. The electrical conductivity (EC) of the soil increased at higher concentrations of digested spentwash, with values of 0.202 dS m⁻¹ at 2.5% concentration and 0.553 dS m⁻¹ at 50% concentration in comparison to the control (EC 0.111 dS m⁻¹), where the plants were irrigated with water. A single application (pre-sowing amendment) of treated spentwash did not raise the EC of the soil beyond 0.262 dS m⁻¹ even at the 500 m³ ha⁻¹ rate. With an increase in the concentration of digested spentwash, either used along with irrigation or as soil amendment, there was a significant increase in the organic C, total N and P contents in the soil compared with the control after the harvesting of chickpea.

Sachin *et al.* (2012) studied the ferti-irrigational effect of distillery effluent (DE) concentrations such as 10, 25, 50, 75 and 100% along with control (Bore well water-BWW) on soil properties after harvest of egg plant. The DE concentrations had significant (P<0.01) effect on EC, Cl⁻, Mg²⁺, OC, HCO₃⁻, exchangeable Na⁺, available K⁺, Ca²⁺, TKN, available P and SO₄²⁻, whereas non-significant (P>0.05) effects were observed for water holding capacity (WHC) and bulk density (BD) of the soil. Irrigation with 100% concentration of DE, increased the EC (+63.46%), Cl⁻ (+292.37%), Mg²⁺ (+1162.72%), OC (+3763.63%), exchangeable Na⁺ (+264.29%), available K⁺ (+48.39%),

Ca²⁺ (+815.74%), Total N (+1449.18%), available P (+338.83%), SO₄²⁻ (+80.07%), while decreased the pH (-17.85%) in effluent irrigated soil.

Vinod Kumar and Chopra (2013) revealed that soil characteristics after irrigation of *V. radiata* with different concentrations of distillery effluent (DE) in both the rainy and summer seasons. Soil irrigated with 100% DE showed increase in EC (88.51-106.63%), OC (3813.95-4215.21%), Na⁺ (273.87-276.12%), K⁺ (69.96-75.79%), Ca²⁺ (1191.21-1221.97%), Mg²⁺ (8379.41-9389.59%), Fe²⁺ (450.56-557.46%), Total N (1336.66-1346.50%), PO₄³⁻ (329.83-340.66%), SO₄²⁻ (130.26-154.56%), Zn (398.73-439.50%), Cd (2100.00-2245.45%), Cu (439.10-459.51%), Mn (2561.11-2973.68%) and Cr (1661.11-1964.28%) and decrease in moisture content (18.84-22.69%), WHC (13.26-15.61%), BD (1.40%) and pH (16.51-17.52%) of the soil in comparison to bore well water (control) irrigated soil in both seasons. A significant increase in the OC, Na⁺, K⁺, Ca²⁺, Mg²⁺, Fe²⁺, TKN, PO₄³⁻, SO₄²⁻, Zn, Cd, Cu, Mn and Cr contents of the soil might be attributed to higher organic load of distillery effluent.

2.6 Conclusion

Thus from the reviews, it is evident that distillery spentwash can be used for soil or foliar application. It is necessary to remove/degrade various pollutants present in the spentwash before discharging it in to the ecosystem. Eco-friendly technologies based on scientific experimentation are needed for effective utilization of distillery spentwash in agriculture without any environmental hazards. Much work has not been done to study the effect of foliar application of diluted spentwash on growth, yield and quality of tomato crop. Also no work has been done on foliar application of fortified distillery spentwash on growth, yield and quality of tomato crop.

III MATERIAL AND METHODS

The research work entitled “Studies on fortification of distillery spentwash for foliar application and its effect on soil properties, growth and yield of tomato” was carried out at the Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru. The work consisted of (a) characterization of distillery spentwash (b) laboratory and green house experiments carried out at the Department of SS & AC and (c) a field experiment in farmer’s field at Gurudevahalli (near M/s Sri Chamundeshwari Sugars Limited), K.M.Doddi, Maddur Taluk, Mandya District during 2013-14 and 2014-15. The details of the material used and methods adopted during the course of investigation are described in this chapter.

3.1 Characterization of biomethanated distillery spentwash

3.1.1 Sample collection

The distillery spentwash samples were collected at 60 days interval from the outlet of biomethanation plant of M/s Sri Chamundeshwari Sugars Ltd., K. M. Doddi, Mandya during 2013 to 2014. Samples were collected in 2 liter plastic cans and stored under refrigerated condition until further analysis.

3.1.2 Analysis of Samples

The biomethanated distillery spentwash was used for the estimation of pH, EC, BOD, COD, total solids, total suspended solids, total dissolved solids, total nitrogen, phosphorus, potassium, sodium, calcium, magnesium, chlorides, sulphates and micronutrients (Zn, Cu, Fe, Mn and B) by following the standard procedures as given in Table 1. The average values are presented in Table 2.

3.1.3 Spentwash sample digestion for nitrogen content

A known volume of distillery spentwash was digested in a Kjeldahl digestion tube using 25 ml of concentrated sulphuric acid and three gram digestion mixture till a bluish green residue was obtained. After cooling, the volume was made up to 100 ml using distilled water and a known volume of aliquot was distilled in an alkaline medium and the liberated ammonia was trapped in boric acid containing mixed indicator and titrated against standard sulphuric acid solution.

3.1.4 Spentwash sample digestion for other elements

A known volume of distillery spentwash was taken in 250 ml conical flask and 15 ml HNO₃ was added and incubated overnight for pre digestion to take place. Then 10 ml of diacid mixture (HNO₃:HClO₄ in 9:4 ratio) was added and digested on a sand bath at 180°C till a snow white residue of 3-5 ml was obtained. After cooling, the volume was made to 100 ml using distilled water and was used for the estimation of all the other elements.

Table 1: Methods followed for the analysis of distillery spentwash

Parameters	Methods	References
pH	Potentiometry	Manivasakam (1987)
EC (dS m ⁻¹)	Conductometry	Manivasakam (1987)
Total, dissolved and suspended solids (%)	Gravimetry	Manivasakam (1987)
BOD (mg L ⁻¹)	Iodometry	APHA (1992)
COD (mg L ⁻¹)	Potassium dichromate method	APHA (1992)
Carbonates (m eq L ⁻¹)	Titrimetry using phenolphthalein indicator	Manivasakam (1987)
Bicarbonates (m eq L ⁻¹)	Titrimetry using methyl orange indicator	Manivasakam (1987)
Total phosphorus (mg L ⁻¹)	Chloromolybdic acid blue colour method	Manivasakam (1987)
Total potassium (mg L ⁻¹)	Flame photometry	Manivasakam (1987)
Calcium (m eq L ⁻¹)	Versenate titrimetry	Manivasakam (1987)
Magnesium (m eq L ⁻¹)	Versenate titrimetry	Manivasakam (1987)
Sulphur (mg L ⁻¹)	Turbidimetry	Manivasakam (1987)
Sodium (mg L ⁻¹)	Flame photometry	Manivasakam (1987)
Chlorides (mg L ⁻¹)	Winkler's method using potassium chromate as indicator	Manivasakam (1987)
Fe, Mn, Zn and Cu (mg L ⁻¹)	Atomic absorption spectrophotometry	Manivasakam (1987)
Boron (mg L ⁻¹)	Diacid digestion and colorimetry using Azomethane-H reagent with continuous flow analyzer	Page <i>et al.</i> (1982)

3.2 Laboratory and greenhouse experiments details: Growth regulating properties of distillery spentwash through bioassay

3.2.1 Laboratory experiment to study the growth regulating properties of distillery spentwash through bioassay

The laboratory experiment was conducted in the post graduate laboratory of the Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, GKVK, Bengaluru during 2013 with eleven different concentrations of

distillery spentwash (undiluted, 1:1, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8, 1:9 and 1:10) and control (Tap water). Cowpea (*Vigna radiata*, var. – PBW 343), Sunflower (*Helianthus annuus*, var.–KBSH 54) and Tomato (*Lycopersicon esculentum*, var. – NS 501) seeds were used for bioassay. Each treatment was replicated thrice and the design was CRD.

Different concentrations of distillery spentwash (undiluted spentwash, 1:1, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8, 1:9 and 1:10) prepared by diluting in tap water were analysed for different chemical parameters and the data are presented in Table 3.

Seeds were surface sterilized with 0.1% HgCl₂ and glasswares were autoclaved before use. Seeds were soaked with respective diluted distillery spentwash used for different treatments and incubated over night (8 hr) and then placed on filter paper in each petridish and equal quantity of diluted distillery spentwash was added and in control tap water was added. Seed germination (%), speed of germination, root length (cm), shoot length (cm) and seed vigour index of seedlings were recorded up to 7 days at 24 hr interval.

Table 3: Chemical properties of diluted distillery spentwash

Treatments	pH	EC (dSm ⁻¹)	N	P	K	Ca	Mg	Na	Fe	Zn	Mn	Cu	B
			(%)			(mg L ⁻¹)							
Undiluted spentwash	7.32	28.5	0.132	0.01	1.31	1456	812	568	26.2	5.61	2.9	1.5	1.08
1:1 dilution	7.35	17.6	0.070	0.004	0.91	789	456	310	25.6	2.34	2.1	0.81	0.51
1:2 dilution	7.36	11.4	0.056	0.005	0.62	658	408	268	22.4	1.68	1.92	0.60	0.38
1:3 dilution	7.37	8.32	0.053	0.003	0.66	628	379	242	21.2	1.62	1.64	0.42	0.08
1:4 dilution	7.38	6.55	0.050	0.005	0.65	602	357	227	19.6	1.56	1.50	0.28	-
1:5 dilution	7.39	5.04	0.044	0.005	0.64	567	328	214	18.4	1.44	1.34	0.16	-
1:6 dilution	7.39	4.64	0.042	0.007	0.61	546	302	197	17.6	1.43	1.20	0.08	-
1:7 dilution	7.40	4.10	0.036	0.004	0.62	510	267	181	17	1.4	1.12	0.01	-
1:8 dilution	7.42	3.50	0.030	0.005	0.6	495	248	164	15.4	1.34	0.98	-	-
1:9 dilution	7.43	3.04	0.028	0.006	0.61	464	229	148	14.6	1.33	0.86	-	-
1:10 dilution	7.45	2.82	0.022	0.005	0.59	448	216	132	12.6	1.3	0.72	-	-
Water	7.52	0.3	0.011	0.009	0.04	210	86	142	5.12	1.27	2.08	0.61	

3.2.2 Determination of germination per cent, speed of germination, seed vigour index, shoot length and root length

The germination percentage was calculated by dividing the number of seeds germinated on each day by total number of seeds taken × 100 and finally added upto the total percentage. Shoot length and root length were measured with scale and expressed as centimeter.

Seed vigour index (SVI) was calculated as per the formula:

SVI = Germination (%) x Seedling length (cm) (Jain and Saha 1971).

Speed of germination was calculated using the formula:

Speed of germination= Number of seeds germinated/Days of first count +----+ No. of seeds germinated/Days of final count.

3.2.3 Greenhouse experiment

Soil sample was collected from ZARS, GKVK, Bengaluru and analyzed for physical and chemical properties. The properties of the soil used for greenhouse experiment are given in Table 4.

Table 4: Initial properties of the soil used for green house experiment.

Parameters		Content
Physical properties		
Particle size distribution	Sand (%)	61.0
	Silt (%)	15.0
	Clay (%)	23.5
	Texture	SCL
Bulk density (Mg m ⁻³)		1.28
Maximum water holding capacity (%)		37.6
Chemical properties		
pH (1:2.5)		6.40
EC (dS m ⁻¹)		0.31
OC (g kg ⁻¹)		5.50
CEC (c mol (p+) kg ⁻¹)		14.7
Available Nitrogen (kg ha ⁻¹)		241.5
Available Phosphorus (kg ha ⁻¹)		42.6
Available Potassium (kg ha ⁻¹)		210.6
Exchangeable Calcium (C mol (p+) kg ⁻¹)		4.50
Exchangeable Magnesium (C mol (p+) kg ⁻¹)		2.10
Available Sulphur (mg kg ⁻¹)		11.7
Exchangeable Sodium (C mol (p+) kg ⁻¹)		0.22
DTPA-Iron (mg kg ⁻¹)		4.20
DTPA-Copper (mg kg ⁻¹)		0.80
DTPA-Manganese (mg kg ⁻¹)		5.60
DTPA-Zinc (mg kg ⁻¹)		1.20
Boron (mg kg ⁻¹)		0.11



Plate 1: General view of laboratory, greenhouse and field experiments

A green house experiment was conducted at GKVK, Bangalore to study the impact of distillery spentwash of different dilutions mainly to identify the best dilution for crops. The details are given below.

Treatments: 12

Replications: 3

Design: CRD

Crops: Tomato, cowpea and sunflower

Treatment details:

- T₁:** Undiluted spentwash
- T₂:** 1:1 Dilution (spentwash: water)
- T₃:** 1:2 Dilution (spentwash: water)
- T₄:** 1:3 Dilution (spentwash: water)
- T₅:** 1:4 Dilution (spentwash: water)
- T₆:** 1:5 Dilution (spentwash: water)
- T₇:** 1:6 Dilution (spentwash: water)
- T₈:** 1:7 Dilution (spentwash: water)
- T₉:** 1:8 Dilution (spentwash: water)
- T₁₀:** 1:9 Dilution (spentwash: water)
- T₁₁:** 1:10 Dilution (spentwash: water)
- T₁₂:** Control (water)

Ten kilograms of soil was taken in plastic pots. Cowpea and sunflower seeds were sown in each pot separately and in case of tomato 21 days old seedlings were transplanted in each pot. At twenty days after sowing of cowpea and sunflower, the spentwash of different dilutions was sprayed as per treatments and for tomato at 15 days after planting the spentwash of different dilutions was sprayed at one week interval up to 3 weeks and growth observations like plant height, number of branches, SPAD chlorophyll meter readings (SCMR) were recorded before and after application of diluted distillery spentwash. The experiment was conducted upto 45 days.

3.3 Field experiments

3.3.1 Description of study area

The experimental site is situated at 12° 36' North latitude and 77° 4' East longitude and at an altitude of 662 meters above mean sea level. It falls under Southern Dry Zone (Agro-Climatic Zone VI) of Karnataka. The experimental site is located at a distance of 25 km from Vishveshwaraiah Canal Farm (V.C. Farm), Mandya. Since V. C. Farm, is the nearest Zonal Agricultural Research Station, the weather data from the station are used for interpretation of results and the same are described in this chapter.

3.3.2 Climatic conditions

Data on normal weather (1976-2014) and actual for the period under study (November 2013 to December 2014) and deviations from the normal with respect to mean monthly total rainfall, maximum and minimum temperatures and relative humidity are presented in Tables 5 and 6 and depicted in Fig. 1 and 2.

3.3.2.1 Normal climatic condition

The normal rainfall of the station during 2013-14 (1st season crop growth period) was 88.5 mm. The major portion of it was received during November. The mean maximum air temperature ranged from 26.2°C to 31.9°C and mean minimum air temperature ranged from 14.2°C to 18.4°C. The highest mean maximum temperature was recorded during March (31.9°C) followed by February (29.8°C). The lowest mean minimum temperature was observed during December (14.2°C). The mean monthly maximum and minimum relative humidity ranged from 80 to 87.0 and 36.0 to 48 per cent, respectively.

The normal annual rainfall of the station during 2014-15 (2nd season of crop growth period) was 446.6 mm and the major portion of it was received from September and October. The mean maximum air temperature ranged from 26.3°C to 28.4°C and mean minimum air temperature ranged from 14.5°C to 19.8°C. The highest mean maximum temperature was observed during September (28.4°C). The lowest mean minimum temperature was observed during December (14.5°C). The mean monthly maximum and minimum relative humidity ranged from 83 to 90 and 43 to 58 per cent, respectively.

3.3.2.2. Actual weather conditions during the period of experimentation

The actual rainfall was less during both 2013-14 (77.8 mm) and 2014-15 (315.0 mm) as compared to normal rainfall. During the crop growth period of 2014-15, August month recorded the higher rainfall (111.6 mm) and it was more than the normal rainfall for the month under consideration.

Table 5: Meteorological data indicating monthly normal, actual and deviation during 2013-14 at ZARS, V.C. farm, Mandya (1st season crop growth period).

Month	Total rainfall (mm)			Mean air temperature (°C)						Mean relative humidity (%)					
				Maximum			Minimum			Maximum			Minimum		
	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D
Nov 13	53.3	56.4	3.1	26.6	29.1	2.5	16.4	16.6	0.2	81	90	9	48	56	8
Dec 13	14.4	1.4	-13	26.2	27.9	1.7	14.2	12.5	-1.7	80	88	8	41	49	8
Jan 14	1.4	0.0	-1.4	29.2	30.2	1.0	14.6	19.3	4.7	87	88	1	41	51	10
Feb 14	4.4	0.0	-4.4	29.8	32.8	3.0	16.0	21.8	5.8	85	89	4	38	50	12
Mar 14	15.0	20.0	5.0	31.9	33.5	1.6	18.4	21.9	3.5	84	90	6	36	47	11
Total	88.5	77.8	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6: Meteorological data indicating monthly normal, actual and deviation during 2014-15 at ZARS, V.C. farm, Mandya (2nd season crop growth period).

Month	Total rainfall (mm)			Mean air temperature (°C)						Mean relative humidity (%)					
				Maximum			Minimum			Maximum			Minimum		
	N	A	D	N	A	D	N	A	D	N	A	D	N	A	D
Aug	73.6	111.6	38.0	28.3	29.4	1.2	19.8	18.7	-1.1	88	90	2	58	53	-5
Sep	152.5	28.2	-124.3	28.4	29.6	1.3	19.8	18.5	-1.3	88	90	2	56	56	0
Oct	149.9	141.2	-8.7	28.2	30.4	2.2	19.4	18.5	-0.9	90	91	1	56	63	7
Nov	56.4	10.0	-46.4	26.7	29.3	2.6	17.0	17.0	0.0	84	90	6	51	50	-1
Dec	14.2	24.0	9.8	26.3	28.5	2.2	14.5	16.2	1.6	83	90	7	43	29	-14
Total	446.6	315.0	-	-	-	-	-	-	-	-	-	-	-	-	-

Note: N: Normal A: Actual D: Deviation from normal
 Normal values are average of 40 years (1973-2013)

The mean maximum temperature was more than the normal for all the months during crop growth periods. The mean minimum air temperature was higher in the month of March (21.9⁰C) during 2013-14 and December (16.2⁰C) during 2014-15. The mean monthly maximum relative humidity of 88 and 90 per cent were observed during both the years. The mean monthly minimum relative humidity ranged from 47 to 56 per cent and 29 to 63 per cent during 2013-14 and 2014-15, respectively whereas the maximum was recorded in the month of November (56 %) and October (63 %) during 2013-14 and 2014-15, respectively.

3.3.3 Soil characteristics of experimental site

Two experiments were conducted in a single block of land. Experiment-I: To study the effect of foliar application of diluted distillery spentwash on tomato crop for two seasons. Experiment-II: To study the effect of foliar application of fortified distillery spentwash on tomato crop for two seasons. Composite soil sample was collected from 0-15 cm depth of soil from the experimental plot and analyzed for physical and chemical properties. The soil properties of the experimental plot at Gurudevarahalli, Maddur Taluk, Mandya District are given in Table 7.

Table 7: Initial properties of soil of experimental plot collected from farmer's field.

Parameters		Field Experiment-I & II
Physical properties		
Particle size distribution	Sand (%)	68.1
	Silt (%)	14.0
	Clay (%)	17.5
	Texture	Sandy Loam
Bulk density (Mg m ⁻³)		1.30
Maximum water holding capacity (%)		34.9
Chemical properties		
pH (1:2.5)		7.55
EC (dS m ⁻¹)		0.15
OC (g kg ⁻¹)		4.20
CEC (c mol (p+) kg ⁻¹)		14.1
Available Nitrogen (kg ha ⁻¹)		223.2
Available Phosphorus (kg ha ⁻¹)		30.5
Available Potassium (kg ha ⁻¹)		360.5
Exchangeable Calcium (C mol (p+) kg ⁻¹)		7.5
Exchangeable Magnesium (C mol (p+) kg ⁻¹)		3.2
Available Sulphur (mg kg ⁻¹)		18.6
Exchangeable Sodium (C mol (p+) kg ⁻¹)		0.44
DTPA-Iron (mg kg ⁻¹)		7.64
DTPA-Copper (mg kg ⁻¹)		0.64
DTPA-Manganese (mg kg ⁻¹)		4.98
DTPA-Zinc (mg kg ⁻¹)		1.04
Boron (mg kg ⁻¹)		0.28

3.3.4 History of experimental plot

During the *kharif* season of 2012, finger millet was grown under rainfed condition in the experimental site.

3.4 Experimental details:

3.4.1 Field experiment-I: To study the effect of different dilutions of distillery spentwash as a foliar spray on growth and yield of tomato.

The experiments were conducted during November 2013 and August 2014. The experimental details are as follows;

Location	: Gurudevahalli, Maddur Taluk, Mandya District.
Name of the farmer	: Chikkathammegowda
Crop	: Tomato
Variety	: NS-501
Spacing	: 120 cm X 45 cm
Season	: <i>Rabi</i> 2013-14 and <i>Kharif</i> 2014-15
Number of treatments	: 13
Number of replications	: 3
Design	: RCBD
Gross Plot size	: 7.2 m × 4.5 m (6 rows with 10 plants per row)
Net Plot size	: 6.0 m × 3.6 m (5 rows with 8 plants per row)

Treatment details

T ₁	100% RDF + 4 sprays of undiluted distillery spentwash
T ₂	100% RDF + 5 sprays of undiluted distillery spentwash
T ₃	100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T ₄	100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T ₅	100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T ₆	100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T ₇	100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T ₈	100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T ₉	100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T ₁₀	100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T ₁₁	100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T ₁₂	100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T ₁₃	100% RDF + water spray (5 times)

Note: 1) RDF 180:120:150 kg N P₂O₅ K₂O ha⁻¹ and recommended FYM (25 t ha⁻¹) common to all the treatments.
2) First foliar spray was started at 45 days after transplanting.

The experiments were laid out in Randomized Complete Block Design (RCBD) and treatments were replicated thrice. The plan of layout of the field experiment-I is depicted in Fig 3.

The field experiments were carried out with tomato-tomato sequence without disturbing the plots to study the foliar application of diluted distillery spentwash on crop growth, yield, quality of tomato crop and soil properties.

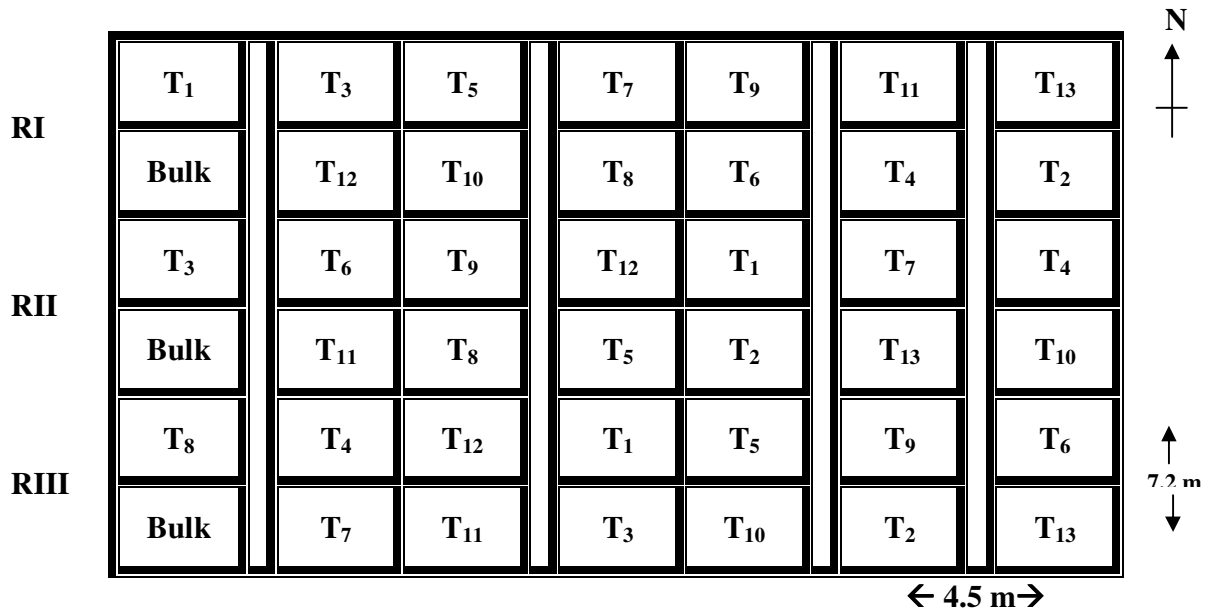


Fig. 3: Layout plan of experiment-I

3.4.2 Field experiment-II: To study the effect of fortified spentwash on growth, yield, quality of tomato and soil properties.

The experiments were conducted during November 2013 and August 2014. After analyzing the distillery spentwash for nutrient composition, the spentwash was fortified with nutrients in different combinations as given below,

SW 1: N-2%, P-1.0% and K-1%

SW 2: SW 1+ micro-nutrients (Zn 100 ppm and B 50 ppm)

Fortification of distillery spentwash

Fortification of distillery spentwash with liquid ammonia (NH₃), zinc sulphate (ZnSO₄) and borax was done to increase the concentration of nitrogen to 2%, zinc to 100 ppm and boron to 50 ppm taking into consideration, the quantity of nitrogen, zinc and boron presented in spentwash. For preparation of fortified SW-1, calculated quantity of liquid ammonia was added to get 2% nitrogen. For enhancing the P content of spentwash

calculated quantity of phosphoric acid was added but it led to precipitation of some of the elements. Hence it was not possible to fortify spentwash with 1.0 % P₂O₅. Fortification with potassium was not done as the potassium content in spentwash is around one per cent. For preparation of fortified spentwash-2, calculated quantity of zinc sulphate and borax were added to fortified spentwash-1. The chemical parameters of fortified distillery spentwash are presented in Table 8.

Table 8: Chemical properties of fortified distillery spentwash

Composition	pH	EC (dSm ⁻¹)	N	P	K	Zn	B	Ca	Mg	Fe	Mn	Cu
			(%)			(mg L ⁻¹)						
Spentwash (SW)	7.32	28.5	0.13	0.02	1.11	5.61	1.08	1456	812	26.2	2.9	1.5
Sw+Liquid ammonia	9.12	22.0	2.05	0.01	1.15	5.24	1.12	1242	742	19.6	2.1	1.1
Sw+Liquid ammonia+ Zinc sulphate+ Borax	7.48	20.7	1.97	0.004	1.19	96.4	51.1	1056	510	25.4	2.49	1.28

3.4.3 Experimental details:

Location	: Gurudevarahalli, Maddur Taluk, Mandya District.
Name of the farmer	: Chikkathammegowda
Crop	: Tomato
Variety	: NS-501
Spacing	: 120 cm X 45 cm
Season	: <i>Rabi</i> 2013-14 and <i>Kharif</i> 2014-15
Number of treatments	: 11
Number of replications	: 3
Design	: RCBD
Gross Plot size	: 7.2 m × 4.5 m (6 rows with 10 plants per row)
Net Plot size	: 6.0 m × 3.6 m (5 rows with 8 plants per row)

Treatment details

- T₁ 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days intervals
- T₂ 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days intervals
- T₃ 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days intervals
- T₄ 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days intervals
- T₅ 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days intervals
- T₆ 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days intervals
- T₇ 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days intervals
- T₈ 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days intervals
- T₉ 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days intervals
- T₁₀ 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days intervals
- T₁₁ RDF with water sprays (6 times)

Note: 1) RDN- Recommended Dose Nitrogen, RDF- Recommended Dose Fertilizers
RDF-180:120:150 kg N P₂O₅ K₂O ha⁻¹

2) Recommended FYM (25 t ha⁻¹) common to all the treatments

3) SW1-Spentwash fortified with nitrogen, SW2-Spentwash fortified with N, Zn and B.

4) First foliar spray was started at 45 days after transplanting.

The experiment was laid out in randomized complete block design (RCBD) and the treatments were replicated thrice. The plan of layout of the field experiment-II is depicted in Fig 4.

The field experiments were carried out with tomato-tomato sequence without disturbing the plots to study the effect of foliar application of fortified distillery spentwash on crop growth, yield and quality of tomato and soil properties.³

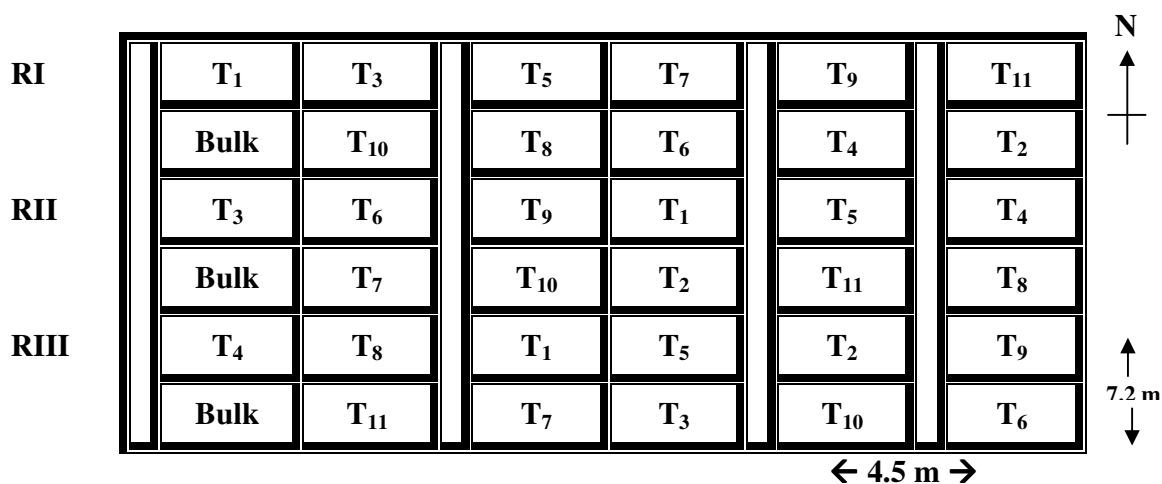


Fig. 4: Layout plan of experiment-II

3.5 Details of cultivation

3.5.1 Preparation of main field

The experimental soil was brought to fine tilth by ploughing and harrowing. Farmyard manure was applied at the rate of 25 tonnes per hectare, incorporated in to the soil 15 days prior to transplanting. The ridges and furrows were opened at spacing of 120 cm part.

3.5.2 Application of fertilizers

The fertilizer dose recommended by IIHR, Bengaluru (180:120:150 N P₂O₅ K₂O kg ha⁻¹, respectively) for tomato crop was applied to all the plots. At the time of transplanting, 50 per cent of recommended dose of nitrogen through urea and full dose of phosphorus through single super phosphate and 50 per cent of potassium through muriate of potash were applied in small furrows at a depth of 10 cm and covered with soil. The remaining 50 per cent of nitrogen and potassium were top dressed in the equal split doses after 4 and 8 weeks of planting for experiment-I and experiment-II .

3.5.3 Preparation of diluted distillery spentwash

Different concentrations of distillery spentwash (1:1, 1:2, 1:3, 1:4 and 1:5) were prepared by using spentwash and water. Foliar application of distillery spentwash was started at 45 days after transplanting at ten days interval.

3.5.4 Preparation of nutrient solution (fortified spentwash) for foliar spray

The spray solution of N (2%), Zn (100 ppm) and B (50 ppm) were prepared to the desired concentration or strength by dissolving calculated quantities of liquid ammonium, zinc sulphate and borax in water and then added to measured quantities of distillery spentwash and to get the required concentration as follows.

Concentration	Quantity of nutrients, spentwash and water required per plot (7.2 m X 4.5 m) for foliar spray as per standard spray solution of 650 L ha ⁻¹				
	Liquid ammonium (ml)	Zinc sulphate (g)	Borax (g)	Spentwash (L)	Water (L)
Nitrogen (2 %)	35.1	-	-	1.49	0.77
Zinc (100 ppm)	-	6.15	-		
Boron (50 ppm)	-	-	6.42		

The calculated quantities of fertilizers were used to prepare SW-1 and SW-2 and they were sprayed to the respective plots at different intervals as per the treatments.

3.5.5 Transplanting

Light irrigation was provided to both the experimental plots, a day prior to transplanting. Healthy uniform seedlings of 24 days old were planted on the slopes of ridges at a distance of 45 cm accommodating 10 seedlings in a row and at a row spacing of 120 cm (60 plants per plot). Gap filling was done within 10 days after transplanting in such spots where seedlings failed to establish.

3.5.6 After care

Hand weeding was done once in 15 days to keep the plots free from weeds. Top dressing with urea was done from 4 weeks after planting followed by earthing up. Recommended plant protection measures were taken up whenever required.

3.6 Observations recorded

Observations were recorded from five randomly selected and labeled plants from each treatment for growth, yield and quality parameters.

3.6.1 Growth parameters

3.6.1.1 Plant height (cm)

The plant height was recorded in centimeters from ground level to apex of the plant. It was recorded at 30, 60 and 90 days after transplanting and at harvest. The mean height was calculated by averaging the values of five marked plants at random.

3.6.1.2 Number of branches per plant

Number of branches per plant was recorded at 30, 60 and 90 days after transplanting and at harvest and mean number of branches per plant was calculated.

3.6.1.3 SPAD Chlorophyll meter reading (SCMR)

Amongst several leaf characters, leaf thickness and chlorophyll content determines the leaf transmittance. Leaf nitrogen content normally influences the leaf chlorophyll content. A device has been developed by Minolta company, New Jersey USA (SPAD-502) which measures the light attenuation at 430 nm (The peak wave length absorption by chlorophyll a and chlorophyll b) and at 750 nm (near infrared) with no transmittance. The unitless value measured by the chlorophyll meter is termed as SCMR (SPAD Chlorophyll Meter Reading) which indicates the relative amount of leaf chlorophyll. The SPAD meter is a simple hand-held instrument, which operates with DC power of three volts.

The SPAD chlorophyll meter readings were taken at 30, 60 and 90 days after transplanting and at harvest in three compound leaves per plant *i.e.* top, middle and bottom leaves from five randomly selected plants. The average SCMR value was computed.

3.6.1.4 Per cent fruit set

The fruit set percentage was estimated by the ratio of number of fruits to the number of flowers produced by the clusters of each plant and that was multiplied by 100. Fruit set percentage was worked out separately for bottom, middle and top position and averages for these positions were expressed as per cent fruit set per plant. The per cent fruit set was calculated by using the formula

$$\text{Per cent fruit set} = \frac{\text{No. of fruits per cluster}}{\text{No. of flowers per cluster}} \times 100$$

3.6.2 Yield parameters

3.6.2.1 Number of fruits per plant

The total number of fruits harvested from five plants was counted and expressed as number of fruits per plant.

3.6.2.2 Weight of 10 fruits

Weight of 10 fruits was determined by weighing randomly selected 10 fruits in each treatment.

3.6.2.3 Fruit yield per plant (kg)

Fruit yield per plant was obtained by adding the weight of all the fruits harvested from the plant during fruiting period and expressed in kilograms.

3.6.2.4 Fruit yield per plot (kg)

The weight of the fruits from all the plants from a net plot harvested at each picking were added and expressed in kilograms/plot.

3.6.2.5 Fruit yield per hectare (t ha⁻¹)

The weight of the fruits harvested treatment wise from each net plot and from each replication was recorded. The total yield per ha was estimated based on the fruit yield per net plot from each harvest and was expressed tonnes per hectare (t ha⁻¹).

3.6.3 Quality parameters

3.6.3.1 Total soluble solids content (°Brix)

A drop of randomly selected (treatment wise) tomato fruit juice was used to determine the TSS with the help of hand refractometer and the value was recorded as °Brix at room temperature. Necessary corrections were effected to 25°C.

3.6.3.2 Ascorbic acid content (mg 100⁻¹ g)

The ascorbic acid content was estimated titrimetrically using 2, 6 Dichlorophenol indo phenol dye as per modified procedure of A.O.A.C., (1997)

Five gram of fresh fruit juice was taken and diluted to a known volume with four per cent oxalic acid. This was filtered through muslin cloth to get a clear juice. Five ml of aliquot was titrated against 2, 6- Dichlorophenol indo phenol dye. The result was expressed as mg of ascorbic acid per 100 g of fruit juice (Srivastava and Singh, 1993).

$$\text{Ascorbic acid} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up} \times 100}{(\text{mg } 100^{-1} \text{ g}) \quad \text{Volume of filtrate taken} \times \text{Wt. or volume of sample taken}}$$

3.6.3.3 Lycopene content (mg 100⁻¹ g)

The lycopene content of tomato fruit was analyzed by using the procedure outlined by Ranganna (1977).

One gram of blended fruit sample was taken in to a mortar and pulp was extracted repeatedly with acetone until the residue turned colorless. The acetone extract was transferred to a separating funnel containing 10 to 15 ml of petroleum ether and mixed gently. Carotenoid pigments were taken in to petroleum ether layer by diluting the acetone with water. Petroleum ether containing pigment was transferred to 25 ml volumetric flask and diluted up to mark with petroleum ether. Then one ml of aliquot was further diluted to 10 ml with petroleum ether and absorbance or OD was read in a spectrophotometer at 530 nm. Lycopene content (mg 100⁻¹ g) in fruit was calculated by using the formula

$$\text{Lycopene} = \frac{3.1206 \times \text{OD of sample} \times \text{Volume made up} \times \text{Dilution} \times 100}{\text{Weight of sample} \times 1000}$$

3.7 Collection of soil and plant samples

3.7.1 Soil sampling and analysis

The representative soil samples were collected at 0-15 cm depth from each plot after harvest of the crop. Soil samples were shade dried, powdered and analyzed for different parameters following standard procedures as described in Table 9.

Table 9: Methods followed for the analysis of soil samples

Parameters	Methods	References
Physical analysis		
Texture	International pipette	Piper (1966)
Bulk density (Mg m^{-3})	Core sampler	Piper (1966)
MWHC (%)	Keen Raczkowski Cup	Piper (1966)
Chemical analysis		
pH (1:2.5)	Potentiometry	Jackson (1973)
EC (dS m^{-1})	Conductometry	Jackson (1973)
Organic Carbon (g kg^{-1})	Wet oxidation	Walkey and Black (1934)
Cation Exchange Capacity ($\text{c mol (p+)} \text{ kg}^{-1}$ soil)	Sodium acetate leaching	Jackson (1973)
Available N (kg ha^{-1})	Alkaline potassium permanganate	Subbiah and Asija (1956)
Available P_2O_5 (kg ha^{-1})	Olsen's extractant, Spectrophotometry	Jackson (1973)
Available K_2O (kg ha^{-1})	NH_4OAc extractant, Flame photometry	Jackson (1973)
Exchangeable Ca [$\text{c.mol (p}^+) \text{ kg}^{-1}$]	NH_4OAc extractant, Versenate titrimetry	Jackson (1973)
Exchangeable Mg [$\text{c.mol (p}^+) \text{ kg}^{-1}$]	NH_4OAc extractant, Versenate titrimetry	Jackson (1973)
Exchangeable Na [$\text{c.mol (p}^+) \text{ kg}^{-1}$]	NH_4OAc extractant, Flame photometry	Jackson (1973)
Available S (mg kg^{-1})	$\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ extractant, Turbidimetry	Black (1965)
DTPA extractable Fe, Mn, Zn and Cu (mg kg^{-1})	Atomic absorption spectrophotometry	Lindsay and Norvell (1978)
Available B (mg kg^{-1})	Hot water extraction method and colorimetry using Azomethane-H reagent with continuous flow analyzer	John <i>et al.</i> (1975)

3.7.2 Plant sampling

The leaves, stem and fruit samples of each treatment were drawn at 80 DAT and at harvest and were analyzed for nutrient concentration and then the uptake of nutrients was calculated.

The leaves, stem and fruit samples were analysed for total N, P, K, Ca, Mg, S, Fe, Zn, Mn, Cu and B contents following standard procedures (Table 10).

Table 10: Methods of plant sample analysis

Plant analysis		
Nitrogen (%)	Kjeldahl digestion distillation method	Piper (1966)
Phosphorus (%)	Diacid digestion and colorimetry using vanadomolybdate reagent	Piper (1966)
Potassium (%)	Diacid digestion and Flame Photometer method	Piper (1966)
Calcium (%)	Diacid digestion and Versenate titration	Piper (1966)
Magnesium (%)	Diacid digestion and Versenate titration	Piper (1966)
Sulphur (%)	Diacid digestion and Turbidometry	Piper (1966)
Fe, Mn, Zn and Cu (mg kg ⁻¹)	Diacid digestion and Atomic Absorption Spectrophotometer method	Lindsay and Norvell (1978)
Boron (%)	Diacid digestion and colorimetry using Azomethane-H reagent with Continuous flow analyzer	Page <i>et al.</i> (1982)

3.8 Statistical analysis and interpretation of data

The analysis and interpretation of the data were done using the Fisher's method of analysis and variance technique as given by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' test were 1 and 5 % probability for lab, pot and field experiments, respectively and wherever 'F' test was found significant, the 't' test was performed to estimate critical differences among various treatments.

IV RESULTS AND DISCUSSION

The escalating prices of fertilizers has resulted in application of less quantity of nutrients than the actual crop demand, thus leading to excessive mining of nutrients from soil and deterioration of soil health. In this context, the high concentration of nutrients present in spentwash offers a very good opportunity to use it as a wholesome liquid fertilizer, because it contains appreciable quantity of all the plant nutrients.

An investigation was undertaken to study the effect of foliar application of distillery spentwash on soil properties, growth and yield of tomato crop in the farmer's field at Gurudevahalli, Maddur taluk, Mandya District located in the Southern Dry Zone of Karnataka during the years 2013-14 and 2014-15. The experiments consisted of (a) laboratory and green house experiments conducted at Department of Soil Science and Agricultural Chemistry, GKVK, Bengaluru with tomato, cowpea and sunflower as test crops to find out best dilution of distillery spentwash (b) field experiment conducted in a farmer's field located at Gurudevahalli, Maddur taluk, Mandya district to study the effect of foliar application of diluted distillery spentwash on tomato crop (c) another field experiment at the same location to study the effect of foliar application of fortified (SW 1 and SW 2) distillery spentwash on tomato crop. The results obtained in these experiments are described and discussed in this chapter.

4.1 Weather and crop growth

Environment is a basic and fundamental factor determining the growth of plants. Thus, the fluctuations in weather conditions directly affect the crop growth and development and expected yield. Eghball *et al.* (1995) reported that the management practices may in some cases reduce temporal variability but in other cases have little effect on the year to year variability of crop yields. The year to year fluctuation is primarily a result of variable weather conditions that prevail in a given agro climatic situation. In this context, the weather conditions that prevailed during the period of experimentation would definitely have a direct bearing on the potentiality of any crop in general and tomato in particular. The crop at the location of experiment experienced favourable weather conditions during growth period as indicated by the climatic data in Tables 5 and 6 and depicted in Fig. 1 and Fig. 2. The weather parameters such as rainfall, maximum and minimum temperature and relative humidity were conducive to the crop during the growth period and there was no incidence of any major pest or disease outbreak during the crop growth period.

The actual rainfall during crop growth period was less than normal in all the months except in the month of November and March during 2013. During 2014, the deviation was less as compared to 2013 except in September and November months in which it has registered less rainfall as compared to normal. During crop growth period, the rainfall was well distributed during 2014 when compared to 2013. However, crop growth and development were not affected by rainfall in 2013 since crop was grown under post rainy season and under irrigated conditions but during

2014 crop has suffered due to excess moisture stress for few days during initial and flowering stage. This is because of heavy rain.

The mean maximum temperature was higher than normal in all the months of 2013 and 2014 during crop growth period. With respect to minimum temperature, most of the months were warmer during crop growth period except in the month of December in 2013 and August, September and October during 2014. The mean maximum relative humidity was more than the normal during the experimental period. Whereas, the mean minimum relative humidity was more than the normal during 2013 and shown deviation during 2014 than the normal as it has ranged from -14.0 (December, 2014) to +7.0 % (October, 2014) and it was higher than normal during 2013 and lower than normal during major part of the crop growth period during 2014. These deviations were not so significant in causing marked variation on growth and development of crop. Besides no adverse weather conditions were observed in any part of the crop growth period.

4.2 Characterization of distillery spentwash

Representative treated distillery spentwash samples collected from M/s Chamundeshwari Sugars Limited, K.M.Doddi, Maddur Taluk, Mandya District, at 60 days interval during October 2013 to December 2014 were analyzed for different parameters and the average values are presented in Table 2.

The analysis of the samples revealed that the distillery spentwash was neutral in reaction (pH 7.32) and electrical conductivity was high (28.5 dS m^{-1}). This could be due to the high salt content of spentwash with higher BOD and COD load increased the electrical conductivity of spentwash. The BOD and COD of the effluent sample were 5988 and 33568 mg L^{-1} , respectively. The concentration of nitrogen, phosphorus and potassium were 0.12, 0.04 and 1.02 %, respectively. The spentwash contained calcium, magnesium and sodium to an extent of 1452, 790, 645 mg L^{-1} , respectively. The TS, DS and TSS content were 6.36, 4.68 and 1.68 %, respectively. Chloride content of the effluent was high (4783 mg L^{-1}). The average concentration of iron, manganese, zinc, copper and boron were 22.5, 4.28, 6.52, 2.32 and 1.08 mg L^{-1} , respectively. The sulphate concentration was 672 mg L^{-1} .

Primary spentwash contains all the essential plant nutrient elements in appreciable quantities. The potassium, nitrogen, sulphur and chloride was very high and the concentration of calcium, magnesium was high. It also has small quantities of iron, manganese, zinc and copper, thus it can be used as liquid fertilizer. Kulkarni *et al.* (1987) opined that spentwash contains all the nutrients and also organic matter and hence, it can be used as liquid organic manure.

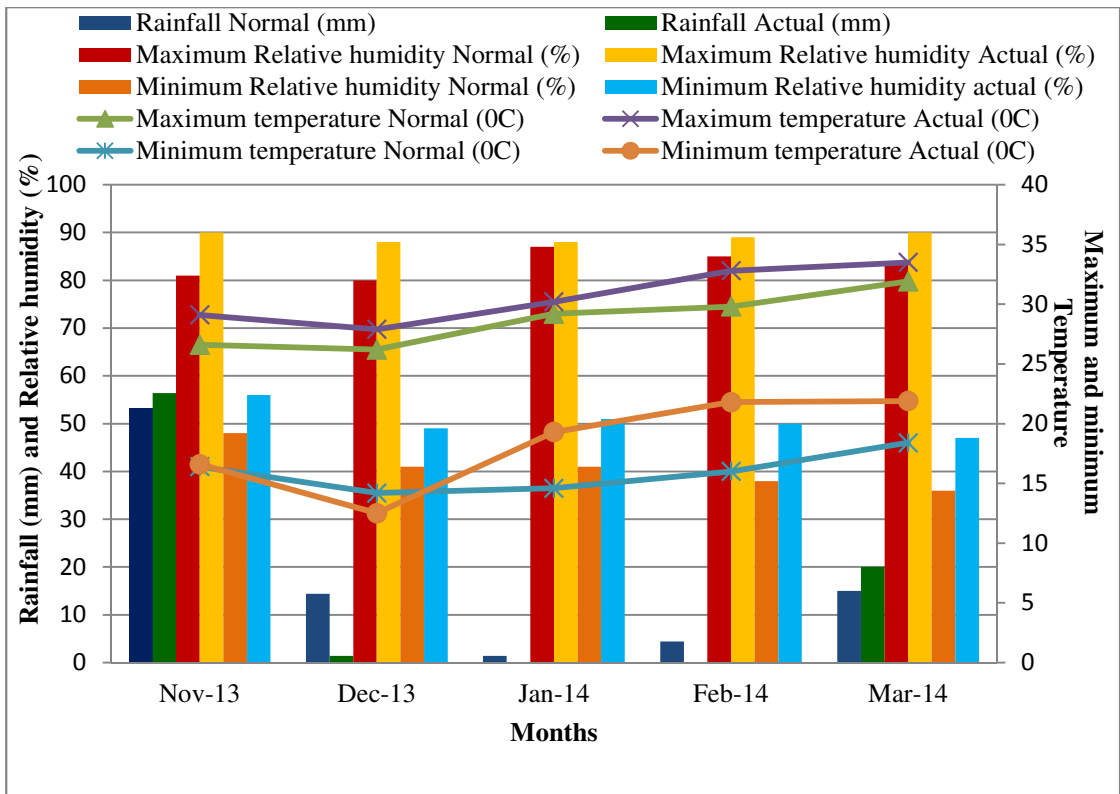


Fig. 1: Meteorological data during crop growth period at ZARS, V.C. Farm, Mandya.

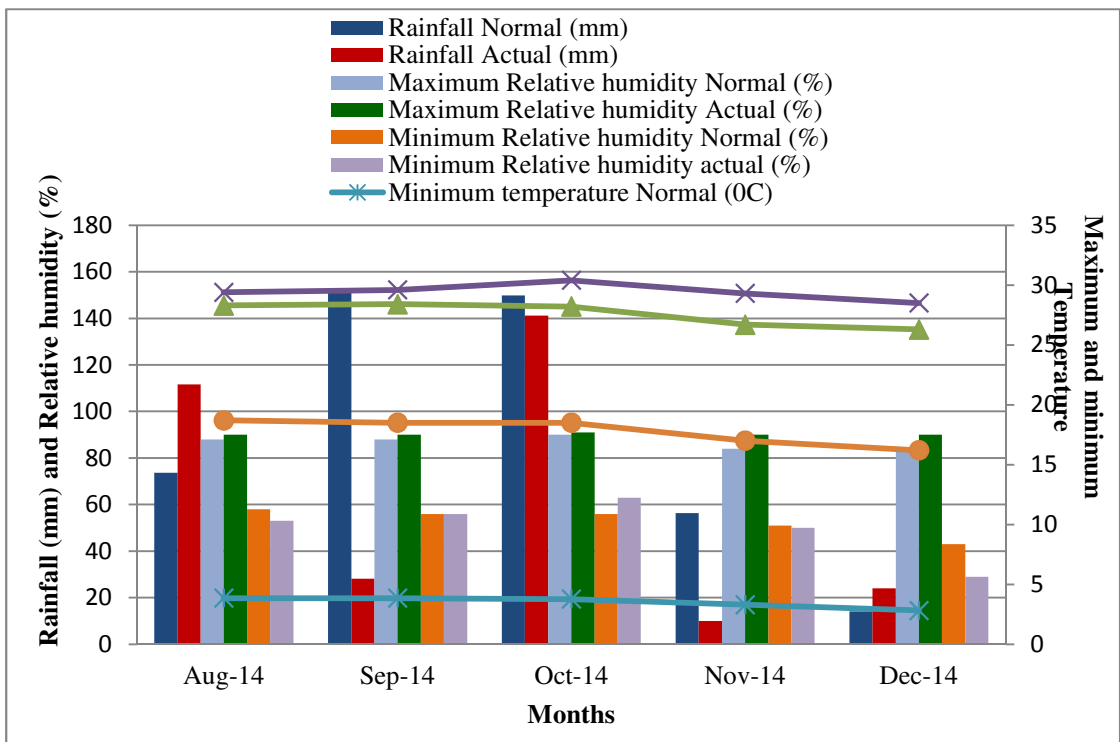


Fig. 2: Meteorological data during crop growth period at ZARS, V.C. Farm, Mandya.

Table 2: Characterisation of distillery spentwash samples collected during October 2013 to December 2014

Parameters	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6	Sample-7	Sample-8	Average
pH	7.30	7.24	7.31	7.32	7.28	7.40	7.40	7.34	7.32
EC (dS m ⁻¹)	28.1	28.9	28.6	28.9	28.2	26.4	29.8	29.2	28.5
TDS (%)	4.68	4.7	4.6	4.52	4.41	4.92	4.68	4.92	4.68
TSS (%)	1.70	1.72	1.74	1.72	1.76	1.72	1.60	1.46	1.68
TS (%)	6.39	6.00	6.01	6.34	6.52	6.72	6.38	6.52	6.36
BOD (mg L ⁻¹)	5640	5860	6200	6480	5840	6590	5540	5980	5988
COD (mg L ⁻¹)	32500	30600	31650	35720	33450	31820	34580	33560	33568
Na (mg L ⁻¹)	651	650	624	662	640	641	645	648	645
N (%)	0.12	0.11	0.12	0.1	0.14	0.12	0.15	0.12	0.12
P (%)	0.04	0.03	0.04	0.02	0.04	0.04	0.04	0.04	0.04
K (%)	1.02	1.01	1.04	1.02	1.02	1.00	0.97	1.03	1.02
SO ₄ (mg L ⁻¹)	673	668	672	689	668	671	685	650	672
Ca (mg L ⁻¹)	1456	1468	1479	1512	1491	1425	1340	1452	1452
Mg (mg L ⁻¹)	792	760	810	850	740	802	780	790	790
Cl (mg L ⁻¹)	4788	4782	4825	4825	4756	4756	4712	4824	4783
Fe (mg L ⁻¹)	22.5	21.2	23.4	24.1	23.5	24.5	20.2	20.8	22.5
Cu (mg L ⁻¹)	2.32	2.41	2.50	2.75	2.15	2.05	2.10	2.30	2.32
Mn (mg L ⁻¹)	4.28	4.35	4.3	4.28	4.38	4.26	4.08	4.28	4.28
Zn (mg L ⁻¹)	6.52	6.15	6.28	6.25	5.86	6.24	6.31	6.42	6.52
B (mg L ⁻¹)	1.08	1.05	1.07	1.08	1.08	1.08	1.08	1.09	1.08

4.3 Growth regulating properties of distillery spentwash through bioassay

4.3.1 Laboratory experiment

The data pertaining to the effect of distillery spentwash at different dilutions on seed germination, speed of germination, root length, shoot length and vigour index of cowpea, sunflower and tomato seeds are presented in tables 11 to 13.

4.3.1.1 Germination (%) and speed of germination

The crops differed widely in their response to different dilutions of distillery spentwash with respect to germination (%), speed of germination, root length, shoot length and vigour index.

Germination per cent differed significantly due to the application of distillery spentwash at different dilutions at 2nd, 3rd, 4th and 5th day after sowing of cowpea, sunflower and tomato seeds in petriplates (Table 11 and Plate 2). On 2nd day, higher germination per cent (83.3) of cowpea was observed in the treatment which received 1:6 dilution of distillery spentwash and it was on par with other treatments except 1:4, 1:3 and 1:2 (spentwash:water) dilutions of distillery spentwash. But there was no germination on 2nd in 1:1 and undiluted distillery spentwash. On 3rd, 4th and 5th day after sowing, 100 per cent germination was noticed in the treatments which received diluted distillery spentwash from 1:5 dilution onwards upto 1:10 dilution and also water spray. No germination or very poor germination per cent of cowpea was observed due to undiluted distillery spentwash on 3rd, 4th and 5th day. Significantly higher speed of germination was observed in the treatments which received diluted distillery spentwash from 1:5 dilution onwards upto 1:10 dilution and also in water spray treatment and speed of germination of cowpea was very low in undiluted spentwash in cowpea (Table 13).

In sunflower, higher germination per cent (65.3) was observed in the treatment which received 1:6 dilution of distillery spentwash (Table 11) and it was on par with all the treatments except 1:4, 1:3 and 1:2 (spentwash:water) dilution of distillery spentwash. Seeds did not germinate on 2nd day in 1:1 and undiluted spentwash. On 3rd, 4th and 5th days after sowing higher or 100 per cent seed germination was noticed in treatments which received diluted distillery spentwash from 1:5 dilution onwards upto 1:10 dilution and also water spray and there was no germination of sunflower seeds due to undiluted distillery spentwash on 3rd, 4th and 5th day. Significantly higher speed of germination of sunflower was observed in the treatments which received diluted distillery spentwash from 1:5 dilution onwards upto 1:10 dilution and also water spray (Table 13).

In tomato crop, the higher seed germination and speed of germination was observed from 1:8 dilution onwards upto 1:10 dilution (spentwash:water) and very poor or no germination was noticed in rest of the treatments on 2nd, 3rd, 4th and 5th day after sowing (Tables 11 & 13). The germination per cent and speed of germination of tomato seeds increased with decrease in the effluent concentration.

Table 11. Germination (per cent) of cowpea, sunflower and tomato seeds as affected by spentwash of different dilutions.

Treatments	Cowpea (%)				Sunflower (%)				Tomato (%)			
	2 nd day	3 rd day	4 th day	5 th day	2 nd day	3 rd day	4 th day	5 th day	2 nd day	3 rd day	4 th day	5 th day
T₁	0	0	20.0	30.0	0	0	0	0	0	0	0	0
T₂	0	10.0	26.7	36.7	0	41.7	46.7	61.7	0	0	0	0
T₃	20.0	36.7	56.7	63.3	15.0	61.7	70.0	80.0	0	0	0	0
T₄	46.7	63.3	80.0	90.0	30.0	70.0	76.7	86.7	0	0	0	0
T₅	56.7	83.3	86.7	93.3	45.0	73.3	83.3	95.0	0	0	0	16.7
T₆	80.0	96.7	100	100	63.3	83.3	86.7	100	0	0	10.0	50.0
T₇	83.3	100	100	100	65.3	86.7	100	100	15.0	25.0	51.7	83.3
T₈	78.3	100	100	100	62.8	88.3	95.0	100	15.0	30.0	60.0	86.7
T₉	80.0	100	100	100	62.2	88.3	100	100	20.0	31.7	93.3	93.3
T₁₀	80.0	100	100	100	62.4	86.7	100	100	25.0	40.0	96.7	100
T₁₁	80.0	100	100	100	64.5	88.3	100	100	30.0	50.0	96.7	100
T₁₂	80.0	100	100	100	65.0	90.0	100	100	36.7	50.0	100	100
S. Em±	1.52	1.98	1.67	2.36	1.18	1.86	2.10	1.60	0.48	0.48	0.96	1.27
C. D. at 1 %	6.02	7.85	6.59	9.32	4.66	7.37	8.30	6.31	1.90	1.90	3.81	5.04
CV	4.62	4.64	3.57	4.83	4.71	4.51	4.60	3.24	7.06	4.41	3.93	4.20

Legend:

- | | |
|-------------------------------------------------------|---------------------------------------------------------|
| Γ ₁ : Undiluted distillery spentwash | Γ ₇ : 1:6 dilution of distillery spentwash |
| Γ ₂ : 1:1 dilution of distillery spentwash | Γ ₈ : 1:7 dilution of distillery spentwash |
| Γ ₃ : 1:2 dilution of distillery spentwash | Γ ₉ : 1:8 dilution of distillery spentwash |
| Γ ₄ : 1:3 dilution of distillery spentwash | Γ ₁₀ : 1:9 dilution of distillery spentwash |
| Γ ₅ : 1:4 dilution of distillery spentwash | Γ ₁₁ : 1:10 dilution of distillery spentwash |
| Γ ₆ : 1:5 dilution of distillery spentwash | Γ ₁₂ : Water |

The germination per cent gradually increased from 2nd to 5th day in all the crops (Table 11.). In cowpea and sunflower crops, significantly higher or 100% germination and higher speed of germination was observed from 1:5 dilution to 1:10 dilution (spentwash:water) and in tomato, higher seed germination was observed from 1:8 to 1:10 dilution on 2nd, 3rd, 4th and 5th day. This may be attributed to the presence of nutrients like N, P, K, Ca and Mg in the effluent at optimum concentration which promoted the growth of plant (Kakar *et al.* 2010).

At higher concentrations, the distillery spentwash showed inhibitory effect on seed germination in all the crops. Inhibition of seed germination may be due to high concentration of dissolved salts, which enhance the salinity and conductivity of the absorbed solutes by seed (Gautam *et al.*, 1992 and Singh *et al.*, 2006). Moreover, availability of oxygen for germinating seeds was reduced due to the presence of organic and inorganic chemicals in the spentwash.

Seed germination in all the three crop species increased with decrease in the effluent concentration, The reason for the reduction in germination per cent at higher concentration of distillery spentwash in all the crops could be attributed to higher concentration of inorganic salts and consequently higher EC. At lower dilution (<1:4), fungal growth on seeds was distinctly visible, which may also be one of the factors responsible for poor germination at lower dilution. These results are in conformity with the findings of earlier workers (Neelam and Sahai, 1988; Pandey and Sony, 1994) who also observed a decrease in seed germination with increase in the concentration of the effluent. Similar results were reported by Subramani *et al.* (1995) while studying the effect of distillery effluent on *Vigna radiata*. Ramana *et al.* (2001) also observed similar kind of inhibitory effects of distillery spentwash on germination of mustard, cauliflower and radish seed.

4.3.1.2 Shoot length, root length (cm) and seedling vigour index

Significantly higher root length, shoot length (cm) and vigour index were observed with higher dilution of distillery spentwash (>1:5) than at lower dilution (<1:4) or undiluted spentwash in cowpea, sunflower and tomato (Tables 12 & 13). Decrease in the concentration of distillery spentwash encouraged the growth as evidenced by the shoot length, root length and vigour index of crops. Zalawadia *et al.* (1997) also reported inhibitory effects of distillery effluents on seed germination, seedling growth, fresh weight and dry weight in onion. In cowpea and sunflower crops, higher shoot length (8.61 and 6.66 cm, respectively), root length (3.40 and 3.94cm) and vigour index (1201 and 1061) values were recorded at 1:5 dilution which was on par with 1:6 (8.40 and 6.48 cm), (3.24 and 3.60cm) and (1164 and 1008, respectively) and lower values were observed in undiluted spentwash. But in tomato crop, higher shoot length (7.53 cm), root length (4.54 cm) and vigour index (1208) were recorded at 1:8 dilution which was on par with 1:9 dilution (shoot length 7.32 cm root length 4.10 cm and vigour index 1134 , respectively) and 1:10 dilution (shoot length 7.23 cm root length 3.63 cm and vigour index 1095 , respectively). The values were lower in the rest of treatments.

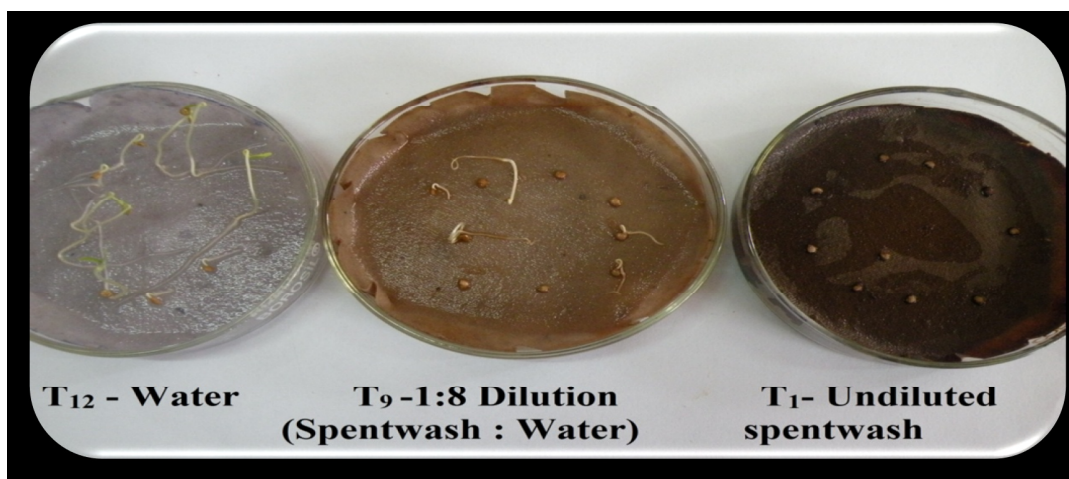
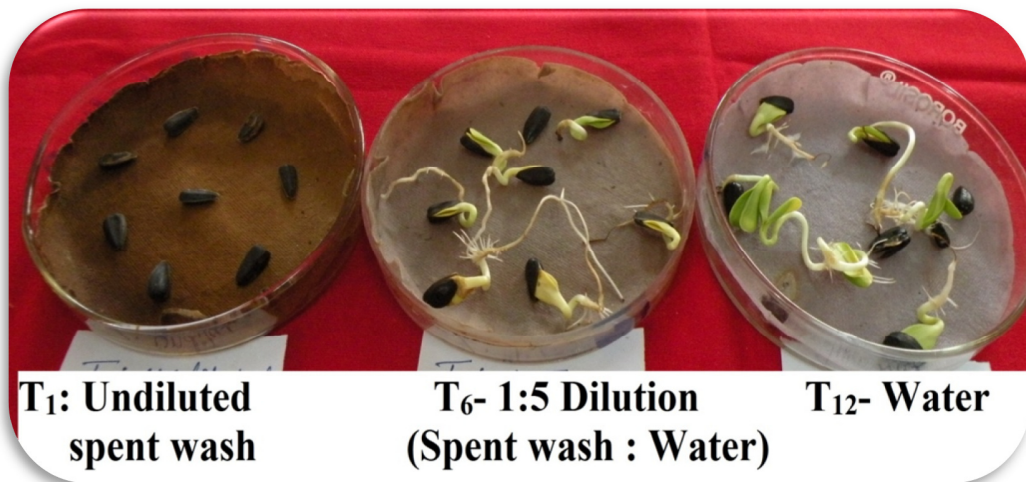


Plate 2: Germination of tomato, sunflower and cowpea seeds under different dilution of distillery spentwash.

Table 12. Shoot and root length (cm) of cowpea, sunflower and tomato as affected by spentwash at different dilutions.

Treatments	Cowpea		Sunflower		Tomato	
	Shoot length	Root length	Shoot length	Root length	Shoot length	Root length
T ₁ : Undiluted distillery spentwash	0.74	0.32	0	0	0	0
T ₂ : 1:1 dilution of distillery spentwash	1.84	0.58	1.68	0.98	0	0
T ₃ : 1:2 dilution of distillery spentwash	2.39	1.86	2.19	1.21	0	0
T ₄ : 1:3 dilution of distillery spentwash	3.18	2.86	3.00	1.18	0	0
T ₅ : 1:4 dilution of distillery spentwash	4.47	3.07	3.41	1.97	1.93	0.66
T ₆ : 1:5 dilution of distillery spentwash	8.61	3.40	6.66	3.94	3.72	1.34
T ₇ : 1:6 dilution of distillery spentwash	8.40	3.24	6.48	3.60	5.02	1.58
T ₈ : 1:7 dilution of distillery spentwash	8.07	2.72	6.26	3.13	6.08	3.17
T ₉ : 1:8 dilution of distillery spentwash	7.67	2.78	6.37	3.29	7.53	4.54
T ₁₀ : 1:9 dilution of distillery spentwash	7.53	2.44	6.41	3.12	7.32	4.10
T ₁₁ : 1:10 dilution of distillery spentwash	7.38	2.24	6.44	3.21	7.23	3.63
T ₁₂ : Water	9.56	3.87	7.02	4.98	8.37	5.42
S. Em±	0.10	0.06	0.10	0.07	0.10	0.05
C. D. at 1 %	0.41	0.23	0.41	0.28	0.38	0.22
CV	3.12	4.12	3.87	4.86	4.28	4.64

Table 13. Seedling vigour index and speed of germination of cowpea, sunflower and tomato seeds as affected by spentwash at different dilution.

Treatments	Speed of germination			Seedling vigour index		
	Cowpea	Sunflower	Tomato	Cowpea	Sunflower	Tomato
T ₁ : Undiluted distillery spentwash	11	0	0	32	0	0
T ₂ : 1:1 dilution of distillery spentwash	17	38	0	89	164	0
T ₃ : 1:2 dilution of distillery spentwash	49	62	0	269	272	0
T ₄ : 1:3 dilution of distillery spentwash	82	75	0	543	363	0
T ₅ : 1:4 dilution of distillery spentwash	96	87	3	703	511	43
T ₆ : 1:5 dilution of distillery spentwash	117	101	13	1201	1061	253
T ₇ : 1:6 dilution of distillery spentwash	120	106	45	1164	1008	550
T ₈ : 1:7 dilution of distillery spentwash	118	103	50	1079	939	801
T ₉ : 1:8 dilution of distillery spentwash	118	104	64	1045	966	1208
T ₁₀ : 1:9 dilution of distillery spentwash	118	104	70	998	953	1134
T ₁₁ : 1:10dilution of distillery spentwash	118	101	76	962	966	1095
T ₁₂ : Water	118	108	80	1342	1200	1379
S. Em±	1.47	1.35	0.44	19.48	14.76	11.78
C. D. at 1 %	5.81	5.35	1.74	77.06	58.37	46.58
CV	2.82	2.84	2.28	4.29	3.65	3.79

The retardation of root and shoot growth at higher concentrations might be due to the scarcity of oxygen in the medium which might have restricted the energy supply (Rath *et.al* 2013). Further they also opined that toxic pollutants present in the effluent, mainly affected the respiration of the root. Less oxygen and more carbon dioxide concentrations in the medium resulted in low aeration that retarded the growth of plants.

4.3.2 Green house experiment

The data pertaining to the effect of foliar sprays of distillery spentwash of different dilutions on growth parameters of cowpea, sunflower and tomato crops are presented in Tables 14 to 16 & Plate 3.

4.3.2.1 Growth parameters

The data on plant height, number of leaves and SPAD chlorophyll meter reading of cowpea, sunflower and tomato as influenced by four foliar sprays of distillery spentwash at different dilutions at weekly interval are presented below.

Plant height: There was no significant difference in plant height of cowpea, sunflower and tomato crops as there was no foliar application of spentwash. (Tables 14, 15 &16).

Plant height varied significantly due to four sprays of diluted distillery spentwash given at weekly intervals (up to 45 days after sowing or transplanting) to all the crops. In cowpea, higher plant height (21.2cm) was recorded in the treatment which received 1:5 dilution of distillery spentwash, it was on par with foliar application of 1:4 dilution (20.0cm) and 1:6 dilution (20.8cm) of distillery spentwash at weekly intervals and lower plant height (13.5 cm) was recorded in the treatment receiving foliar application of undiluted distillery spentwash (Tables 14, 15 &16). In sunflower, significantly higher plant height (52.9cm) was recorded in the treatment which received 1:4 dilution of distillery spentwash and was on par with foliar application of 1:5 dilution (48.3cm) of distillery spentwash at weekly intervals and significantly lower plant height (27.2 cm) was noticed in with foliar application of undiluted distillery spentwash. Significantly higher plant height (27cm) of tomato was recorded in the treatment which received 1:5 dilution of distillery spentwash and it was on par with foliar application of 1:4 dilution (26.2cm) of distillery spentwash at weekly intervals and significantly lower plant height (15.9 cm) was noticed in the treatment receiving foliar application of undiluted distillery spentwash.

Number of leaves: Number of leaves per plant did not differ significantly at 15 days after sowing/transplanting of cowpea, sunflower and tomato crops as there was no foliar application of distillery spentwash.

Number of leaves per plant varied significantly in all the crops due to four sprays of diluted distillery spentwash sprayed at weekly intervals (up to 45 days after sowing or transplanting). In cowpea, more number of leaves (12.0) was recorded in the treatment which received 1:5 and 1:6 dilutions of distillery spentwash, it was on par with foliar application of 1:4 dilution (11.7) and 1:7 dilution (11.0) of distillery spentwash and less number of leaves (7.0) were recorded in the treatment receiving foliar application of undiluted distillery spentwash. In sunflower, significantly more number of leaves (10.0) was recorded in the treatment which received 1:4 and 1:5 dilutions of distillery spentwash, it was on par with foliar application of 1:3 and 1:6 dilutions (9.30) of distillery spentwash at weekly intervals and significantly lower number of leaves (6.0) was noticed due to foliar application of undiluted distillery spentwash. Significantly more number of leaves (7.0) in tomato crop was recorded in the treatment which received 1:8, 1:9 and 1:10 dilutions of distillery spentwash and significantly lower number of leaves (4.3) was due to foliar application of undiluted distillery spentwash (Tables 14, 15 &16).

The lower plant height and number of leaves of cowpea, sunflower and tomato crops (Tables 14, 15 &16) were noticed in the treatment receiving of higher concentration of distillery spentwash as foliar sprays of undiluted and 1:1 diluted distillery spentwash. Ramana *et al.* (2001) reported that higher concentration of effluent had high BOD and COD, and it resulted in nutritional imbalance as well as reduction in the availability of essential nutrients to the plants due to increase in the osmotic pressure of soil irrigated with higher concentration of effluent. According to Saxena *et al.* (1986), the low amount of oxygen in dissolved form due to the presence of higher concentration of solid in the effluent reduce the energy supply through anaerobic respiration leading to restriction in the growth and development of the seedling. Inhibition of seed germination and seedling growth may be due to high levels of dissolved solids which enrich the salinity and conductivity of the absorbed solute by seed before germination (Gautham and Bishoni, 1992). Murkumar and Chauhan (1987) reported that the higher concentration of effluent decreased the dehydrogenase activity that is considered as one of the biochemical changes which might have disrupted germination and seedling growth.

The higher plant height and number of leaves of cowpea, sunflower and tomato crops were noticed in the treatments on foliar application of lower concentration of distillery spentwash especially from 1:4 dilutions onwards upto 1:8 dilution. Rani and Srivastava (1990) reported more absorption of plant nutrients present in spentwash by plants at higher dilutions. Therefore, diluted spentwash increased the growth in terms of shoot length, leaf number and chlorophyll contents.

SPAD chlorophyll meter reading: SPAD reading did not differ significantly at 15 days after sowing/transplanting in cowpea, sunflower and tomato crops as there was no foliar application of distillery spentwash.

Table 14. Plant height (cm), number of leaves plant⁻¹ and SPAD chlorophyll meter (SCMR) of cowpea crop before and after four foliar sprays of distillery spentwash at different dilutions

Treatments	Plant height (cm)		No. of leaves plant ⁻¹		SCMR	
	Before*	After**	Before*	After**	Before*	After**
T ₁ : Undiluted distillery spentwash	10.1	13.5	5.0	7.0	7.6	8.0
T ₂ : 1:1 dilution of distillery spentwash	10.0	16.3	4.7	8.0	6.9	11.2
T ₃ : 1:2 dilution of distillery spentwash	10.0	16.2	5.0	8.7	8.1	11.7
T ₄ : 1:3 dilution of distillery spentwash	11.1	18.2	5.0	9.7	6.9	10.9
T ₅ : 1:4 dilution of distillery spentwash	10.9	20.0	5.0	11.7	7.0	12.4
T ₆ : 1:5 dilution of distillery spentwash	10.3	21.2	5.0	12.0	7.8	12.5
T ₇ : 1:6 dilution of distillery spentwash	10.7	20.8	5.0	12.0	7.7	12.5
T ₈ : 1:7 dilution of distillery spentwash	10.3	19.7	5.0	11.0	7.0	10.5
T ₉ : 1:8 dilution of distillery spentwash	10.1	19.6	5.0	10.7	7.5	10.1
T ₁₀ : 1:9 dilution of distillery spentwash	10.3	17.0	5.0	10.0	8.6	9.3
T ₁₁ : 1:10 dilution of distillery spentwash	11.0	15.3	4.7	9.0	7.6	8.6
T ₁₂ : Water spray	10.6	14.3	4.7	7.7	7.4	8.3
S. Em±	0.4	0.4	0.2	0.3	0.8	0.3
C. D. at 1 %	NS	1.6	NS	1.1	NS	1.2
CV	6.49	3.91	8.30	4.82	3.82	4.82

Before*-At 15 days after sowing (without foliar application of distillery spentwash)

After** - At 45th day after sowing (with 4 sprays of distillery spentwash at weekly intervals)

Table 15. Plant height (cm), number of leaves plant⁻¹ and SPAD chlorophyll meter (SCMR) of sunflower crop before and after four foliar sprays of distillery spentwash at different dilutions

Treatments	Plant height (cm)		No. of leaves plant ⁻¹		SCMR	
	Before*	After**	Before*	After**	Before*	After**
T ₁ : Undiluted distillery spentwash	10.9	27.2	6.0	6.0	5.3	6.3
T ₂ : 1:1 dilution of distillery spentwash	10.6	34.5	6.0	6.7	5.2	7.0
T ₃ : 1:2 dilution of distillery spentwash	11.0	34.2	6.0	8.7	6.6	8.8
T ₄ : 1:3 dilution of distillery spentwash	11.8	46.6	6.0	9.3	5.4	11.3
T ₅ : 1:4 dilution of distillery spentwash	12.5	52.9	6.0	10.0	5.6	11.2
T ₆ : 1:5 dilution of distillery spentwash	11.2	48.3	6.0	10.0	5.9	10.5
T ₇ : 1:6 dilution of distillery spentwash	12.1	41.3	6.0	9.3	6.3	9.3
T ₈ : 1:7 dilution of distillery spentwash	11.1	45.3	6.0	8.7	5.2	9.2
T ₉ : 1:8 dilution of distillery spentwash	11.2	43.4	6.7	9.0	6.0	8.9
T ₁₀ : 1:9 dilution of distillery spentwash	11.5	48.4	6.0	9.0	5.9	9.6
T ₁₁ : 1:10 dilution of distillery spentwash	11.1	46.4	6.3	9.0	5.6	8.9
T ₁₂ : Water spray	11.3	43.5	6.0	8.7	6.8	7.2
S. Em±	0.5	1.0	0.1	0.2	1.2	0.3
C. D. at 1 %	NS	4.0	NS	0.9	NS	1.0
CV	7.78	4.11	3.87	4.70	3.64	4.84

Before*-At 15th days after sowing (without foliar application of distillery spentwash)

After** - At 45th days after sowing (with 4 sprays of distillery spentwash at weekly intervals)



Plate 3: Comparative performance of tomato, sunflower and cowpea crops under different dilution of distillery spentwash.

Table 16. Plant height (cm), number of leaves plant⁻¹ and SPAD chlorophyll meter reading (SCMR) of tomato crop before and after four foliar sprays of distillery spentwash at different dilutions

Treatments	Plant height (cm)		No. of leaves plant ⁻¹		SCMR	
	Before*	After**	Before*	After**	Before*	After**
T ₁ : Undiluted distillery spentwash	13.0	15.9	4.3	4.3	12.5	10.6
T ₂ : 1:1 dilution of distillery spentwash	14.5	19.1	4.0	5.0	11.7	13.4
T ₃ : 1:2 dilution of distillery spentwash	13.8	20.3	4.0	6.0	13.2	17.7
T ₄ : 1:3 dilution of distillery spentwash	14.5	24.5	4.3	5.7	12.8	17.5
T ₅ : 1:4 dilution of distillery spentwash	14.9	26.2	4.0	6.0	13.4	19.2
T ₆ : 1:5 dilution of distillery spentwash	15.8	27.0	4.0	6.0	12.6	21.6
T ₇ : 1:6 dilution of distillery spentwash	15.3	24.3	4.0	6.3	12.6	19.1
T ₈ : 1:7 dilution of distillery spentwash	16.4	22.5	4.0	7.0	13.2	17.5
T ₉ : 1:8 dilution of distillery spentwash	16.6	21.5	4.3	7.0	13.0	16.1
T ₁₀ : 1:9 dilution of distillery spentwash	15.4	19.5	4.0	7.0	13.1	17.2
T ₁₁ : 1:10 dilution of distillery spentwash	15.6	19.0	4.0	6.0	14.5	15.7
T ₁₂ : Water spray	14.9	16.9	4.0	6.0	11.7	12.9
S. Em±	0.6	0.6	0.2	0.1	0.6	0.5
C. D. at 1 %	NS	2.2	NS	0.6	NS	1.8
CV	6.81	4.56	7.07	4.15	7.47	4.76

Before*- At 15 days after transplanting (without foliar application of distillery spentwash)

After**- At 45 days after transplanting (with 4 sprays of distillery spentwash at weekly intervals)

SPAD reading in case of cowpea, sunflower and tomato crops showed significant difference due to 4 sprays of diluted distillery spentwash taken up at weekly intervals (up to 45 days after sowing or transplanting). In cowpea, higher SPAD reading (12.5) was recorded in the treatment receiving 1:5 and 1:6 dilutions of distillery spentwash, which was on par with foliar application of 1:4 dilutions (12.4) of distillery spentwash. In sunflower, significantly higher SPAD reading (11.3) was recorded in the treatment which received 1:3 dilution and it was on par with foliar application of 1:4 dilution (11.2) and 1:5 dilution (10.5) of distillery spentwash at weekly intervals. In tomato, significantly higher SPAD readings (21.6) was recorded in the treatment which received 1:5 dilutions of distillery spentwash (Tables 14, 15 &16). The increase in chlorophyll content in treatment with low concentration of spentwash may be attributed to synthesis of chlorophyll which is accelerated at low concentration and supply of nitrogen and magnesium which help in increasing the leaf chlorophyll content. Similar findings have been reported by Rani and Srivastava 1990; Rath *et al.* 2011.

Lower SPAD readings in cowpea, sunflower and tomato crops (8.0, 6.3 and 10.6) was noticed in the treatment receiving foliar application of undiluted distillery spentwash. Some of the possible reasons for the decrease in chlorophyll contents may be due to lower availability of essential nutrients and also due to poor root growth (Rath *et al.* 2011).

4.4 Field Experiment-I: To study the effect of different dilutions of distillery spentwash as a foliar spray on growth and yield of tomato.

The experiment was carried out for two years in a farmer's field at Gurudevahalli, Maddur taluk, Mandya district during 2013 and 2014. However, the growth, yield and quality parameters and nutrients uptake by tomato crop were lower in all the treatments during 2014 compared to 2013. This could be due to heavy rain at initial stage and at flowering stage during 2014 which resulted in water stagnation for few days in the experimental field. Tomato crop is highly sensitive to water stagnation and hence a decrease in growth, yield and quality parameters was observed during 2014 compared to 2013. However, the soil properties were higher during 2014 compared to 2013, this is because of water stagnation in the respective treatment plots. The results of the two years of field experiments are briefly discussed in the following sections.

4.4.1 Plant growth parameters

The data on plant height, number of branches plant⁻¹ and SPAD meter reading of tomato crop during 2013 and 2014 as influenced by foliar application of diluted distillery spentwash at different growth stages are presented in tables 17, 18 &19 & plate 4).

Plant height

At 30 DAT, plant height and SPAD chlorophyll meter reading did not differ significantly due to foliar application of diluted distillery spentwash during 2013 and 2014. However at 30 DAT, no branches were noticed in tomato crop.

At 60 DAT, plant height showed significant difference due to foliar application of diluted distillery spentwash during 2013 and 2014 (Table 17). Significantly higher plant height was observed in the treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T_{12} : 116.4cm & 104.1cm, respectively) Addition of N, P and K and other plant nutrients through foliar applications of diluted spentwash in addition to recommended dose of fertilizers resulted in improvement of plant growth was reported by Sukanya and Meli (2004). The results are in agreement with findings of Zalawadia *et al.* (1997) who reported that less diluted spentwash gave a higher growth and yield of crops than the more diluted ones. However, it was on par with the application of 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (T_{10} :114.2cm & 101.0 cm respectively), 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution (T_{11} :112.3 cm & 98.3 cm, respectively) and 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution (T_9 :110.4 cm & 97.4 cm, respectively).

Further, significantly lower plant height (82.5 cm and 80.3 cm, respectively) was observed in treatment which received 100% RDF + water spray (T_{13}). This is because of lower availability of nutrients and the treatment T_1 which received 100% RDF + 4 sprays of undiluted distillery spentwash (85.8cm & 82.1cm) during 2013 and 2014 respectively. Distillery effluent contained an excess of various forms of cations and anions which are injurious to plant growth. These findings are in line with the results of Sahai *et al.* (1983). Similar trend was observed at 90 DAT and at harvest.

Pooled analysis of two years data of experiments showed significantly higher plant height (110.2 cm) due to 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T_{12}) compared to other treatments. However, significantly lower plant height was observed in T_{13} which received 100% RDF + water sprays (5 times) (81.4 cm) followed by 100% RDF + 4 sprays of undiluted distillery spentwash at 1:1 dilution (T_1 : 84.0 cm) and 100% RDF + 5 sprays of undiluted distillery spentwash at 1:1 dilution (T_2 : 85.2 cm) Similar trend was observed at 90 DAT and at harvest.

Number of branches plant⁻¹

At 60 DAT, significant difference in the number of branches per plant was observed due to foliar application of diluted distillery spentwash during 2013 and 2014 (Table 18). However, the number of branches were less in the treatments which received water spray and undiluted distillery spentwash compared to foliar application of diluted distillery spentwash. In diluted spentwash, significantly higher number of branches per plant were recorded in treatment T_{12} which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T_{12} : 6.5 & 6.4 respectively) which was on par with T_{10} : 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (6.1 & 5.6, respectively). This might be due to addition of some nutrients required for plant growth

and development supplied through distillery spentwash when applied as foliar spray. However, less number of branches per plant (3.7 & 3.7) was recorded in T₁₃: 100% RDF + water spray (5 times) and T₁ received 100% RDF + 4 sprays of undiluted distillery spentwash (4.4 and 3.9) during 2013 and 2014. This might be due to toxic effect of excessive quantities of soluble salts and other materials present in distillery spentwash might have affected plant growth. Similar trend was observed at 90 DAT and at harvest.

Pooled analysis of data of two years (2013 and 2014) revealed that at 60 DAT, the treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) recorded significantly higher number of branches per plant (6.5). However, significantly lower number of branches per plant (3.7) was observed in treatment T₁₃ which received 100% RDF + water sprays (5 times). Similar trend was observed at 90 DAT and at harvest.

SPAD chlorophyll meter reading

At 60 DAT, SPAD reading showed significant difference with respect to foliar application of diluted distillery spentwash during 2013 and 2014 (Table 19). Significantly higher SPAD reading was observed in the treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂: 23.4 & 22.3, respectively). However, it was on par with the application of 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (T₁₀: 23.0 & 21.9, respectively), 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution (T₁₁: 22.6 & 20.9, respectively) and 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution (T₉: 22.6 & 19.8, respectively). The increase in SPAD reading due to foliar application of lower dilution of distillery spentwash may be attributed to lack of heavy metals in the distillery effluent and probably the availability of N, Fe and Mg which are necessary for the synthesis of chlorophyll. Similar findings have been reported by many workers (Rani and Srivastava 1990; Rath *et al.* 2011).

Further, significantly lower SPAD chlorophyll meter reading was observed in treatment receiving 100% RDF + water sprays (5 times) during 2013 and 2014 (T₁₃: 13.1 and 11.5 respectively). Some of the possible reasons for the decrease in chlorophyll contents may be due to lower availability of essential nutrients and poor root growth (Rath *et al.* 2011). Some of the possible reasons for the decrease in the pigment content may be due to the formation of enzyme chlorophyllase which is responsible for chlorophyll degradation (Krishna and Leelavathi, 2002). Similar trend was observed at 90 DAT and at harvest.

Presentation of data is based on pooled analysis of two years of experiment. Significantly higher SPAD meter reading (22.9) was noticed in treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) followed by 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (T₁₀: 22.5). However, significantly lower SPAD reading was observed in T₁₃ (12.3) treatment which received 100% RDF + water sprays (5 times). Similar trend was observed at 90 DAT and at harvest.

Table 17. Effect of foliar application of diluted distillery spentwash on plant height (cm) at different growth stages of tomato crop grown during 2013 and 2014.

Treatments	Plant height (cm)											
	30 DAT			60 DAT			90 DAT			At harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	68.1	60.8	64.5	85.8	82.1	84.0	104.7	98.5	101.6	111.9	105.4	108.7
T₂	65.8	59.7	62.8	86.5	84.0	85.2	105.6	99.4	102.5	112.1	106.0	109.1
T₃	66.4	59.7	63.0	91.6	87.4	89.5	111.6	101.5	106.6	115.1	108.0	111.5
T₄	65.6	59.7	62.6	92.8	89.5	91.2	112.0	103.8	107.9	115.3	110.4	112.8
T₅	69.4	60.2	64.8	95.6	91.0	93.3	126.4	108.8	117.6	129.3	115.5	122.4
T₆	67.2	60.7	64.0	98.0	92.6	95.3	127.8	111.9	119.8	131.9	118.7	125.3
T₇	67.3	60.2	63.8	101.4	94.3	97.9	130.6	117.4	124.0	134.4	124.2	129.3
T₈	67.6	59.2	63.4	104.2	95.3	99.8	133.6	120.5	127.0	136.9	127.3	132.1
T₉	65.5	59.9	62.7	110.4	97.4	103.9	134.5	125.6	130.1	138.2	132.2	135.2
T₁₀	69.0	57.8	63.4	114.2	101.0	107.6	139.6	128.4	134.0	142.4	135.1	138.8
T₁₁	68.1	59.5	63.8	112.3	98.3	105.3	137.5	126.1	131.8	140.7	132.9	136.8
T₁₂	65.5	59.6	62.6	116.4	104.1	110.2	142.3	130.4	136.3	145.5	137.2	141.4
T₁₃	67.4	59.1	63.2	82.5	80.3	81.4	103.3	96.9	100.1	107.4	101.9	104.7
S. Em±	0.9	0.8	0.9	5.9	4.7	5.4	6.6	4.1	5.9	6.4	4.4	5.5
C. D. at 5%	NS	NS	NS	17.1	13.8	15.4	19.3	12.0	16.9	18.8	12.8	15.5
CV (%)	2.4	2.4	2.4	10.2	8.9	9.8	9.2	6.3	8.7	8.7	6.4	7.6

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 18. Effect of foliar application of diluted distillery spentwash on number of branches plant⁻¹ at different growth stages of tomato crop grown during 2013 and 2014.

Treatments	Numbers of branches plant ⁻¹								
	60 DAT			90 DAT			At harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	4.4	3.9	4.2	9.0	8.5	8.7	9.1	8.7	8.9
T₂	4.7	4.2	4.4	9.2	8.9	9.1	9.1	9.1	9.1
T₃	4.6	4.1	4.4	10.9	9.6	10.2	10.9	9.8	10.4
T₄	4.7	4.2	4.5	11.2	9.8	10.5	11.3	9.9	10.6
T₅	5.3	4.8	5.0	10.7	10.9	10.8	10.9	11.1	11.0
T₆	5.1	4.6	4.8	11.3	11.3	11.3	11.6	11.4	11.5
T₇	4.9	4.4	4.7	11.6	11.1	11.3	11.8	11.5	11.6
T₈	5.2	4.7	5.0	11.9	11.2	11.5	12.0	11.6	11.8
T₉	5.7	5.2	5.5	11.8	11.3	11.5	12.0	11.6	11.8
T₁₀	6.1	5.6	5.8	11.9	11.6	11.7	12.1	11.7	11.9
T₁₁	5.7	5.2	5.5	11.7	11.5	11.6	11.9	11.8	11.9
T₁₂	6.5	6.4	6.5	12.1	11.7	11.9	12.4	11.9	12.2
T₁₃	3.7	3.7	3.7	8.3	8.0	8.2	8.3	8.2	8.3
S. Em±	0.3	0.3	0.3	0.5	0.5	0.5	0.5	0.5	0.5
C. D. at 5%	0.9	0.9	0.8	1.6	1.4	1.5	1.4	1.6	1.4
CV (%)	10.1	11.3	10.5	8.5	8.2	8.6	7.6	8.9	8.1

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash

T₂: 100% RDF + 5 sprays of undiluted distillery spentwash

T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution

T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution

T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution

T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution

T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution

T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution

T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution

T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution

T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution

T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution

T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 19. Effect of foliar application of diluted distillery spentwash on SPAD chlorophyll meter (SCMR) at different growth stages of tomato crop grown during 2013 and 2014

Treatments	SCMR											
	30 DAT			60 DAT			90 DAT			At harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	8.8	9.3	9.0	14.4	13.3	13.9	11.7	10.2	11.0	12.6	8.6	10.6
T₂	9.0	10.0	9.5	15.4	14.1	14.7	12.2	10.5	11.3	12.9	9.4	11.2
T₃	8.7	9.7	9.2	17.5	14.2	15.9	13.2	11.9	12.5	14.9	11.4	13.1
T₄	9.1	10.8	10.0	19.7	15.3	17.5	14.3	12.6	13.4	15.8	11.8	13.8
T₅	9.2	11.2	10.2	19.5	16.2	17.8	15.6	13.2	14.4	17.3	12.3	14.8
T₆	9.4	10.6	10.0	21.1	17.1	19.1	15.7	13.8	14.7	19.2	12.5	15.9
T₇	9.9	10.7	10.3	21.7	17.7	19.7	17.4	14.3	15.9	19.0	13.4	16.2
T₈	9.2	11.2	10.2	22.2	18.7	20.5	17.6	15.5	16.5	19.0	14.5	16.8
T₉	9.9	10.5	10.2	22.6	19.8	21.2	18.4	15.8	17.1	19.9	14.7	17.3
T₁₀	9.4	10.1	9.8	23.0	21.9	22.5	19.1	16.9	18.0	20.6	15.8	18.2
T₁₁	9.7	10.8	10.3	22.6	20.9	21.7	19.1	16.4	17.7	20.5	15.3	17.9
T₁₂	9.7	10.7	10.2	23.4	22.3	22.9	20.4	17.5	19.0	22.0	16.4	19.2
T₁₃	9.0	11.0	10.0	13.1	11.5	12.3	11.0	8.1	9.5	12.2	7.8	10.0
S. Em±	1.1	0.8	1.2	1.0	1.4	1.2	1.3	0.6	1.0	1.1	1.0	1.1
C. D. at 5%	NS	NS	NS	2.9	4.2	3.5	3.9	1.7	2.9	3.1	3.0	3.0
CV (%)	15.7	13.5	16.8	8.8	14.4	11.6	14.8	7.4	12.2	10.5	14.3	12.1

Legend:

- | | |
|------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| T ₁ : 100% RDF + 4 sprays of undiluted distillery spentwash | T ₈ : 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution |
| T ₂ : 100% RDF + 5 sprays of undiluted distillery spentwash | T ₉ : 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution |
| T ₃ : 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution | T ₁₀ : 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution |
| T ₄ : 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution | T ₁₁ : 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution |
| T ₅ : 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution | T ₁₂ : 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution |
| T ₆ : 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution | T ₁₃ : 100% RDF + water sprays (5 times) |
| T ₇ : 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution | |

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

4.4.2 Yield and yield parameters

The crop growth and productivity are influenced by many factors both externally and internally. Nutrient management is one such important factor which largely decides the yield of the crop. The economic yield of a plant is an outcome of a series of integrated interactions of various biological events which takes place during its development in accordance with the availability of light, temperature and supply of water and nutrients (Donald, 1962). The information on per cent fruit set, number of fruits per plant, 10 fruits weight and fruit yield per hectare differed significantly due to foliar application of diluted distillery spentwash compared to water and undiluted distillery spentwash sprays during 2013 and 2014. (Tables 20, 21 and 22).

Per cent fruit set:

During 2013 and 2014, the treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher per cent fruit set (82.5 & 76.2, respectively) which was on par with treatment T₁₀ receiving 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (81.4 & 75.2). This is because of diluted spentwash was able to supply of required nutrients to plants through foliar application. Samuel (1986) reported that spentwash could be used as a complement to mineral fertilizer in sugarcane. While, significantly lower per cent fruit set was recorded in treatment which received 100% RDF + water sprays (5 times) (T₁₃: 63.7 & 60.4, respectively)

The pooled analysis of two years results revealed that the per cent fruit set (Table 20) was significantly higher in the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (79.4). Significantly lower per cent fruit set (62.1) was recorded in the treatment T₁₃ which received 100% RDF + water sprays (5 times).

Number of fruits per plant

The results pertaining to the effect of foliar application of diluted spentwash on the number of fruits per plant are presented in Table 20. Significant increase in the number of fruits per plant was recorded with the foliar application of diluted spentwash over undiluted spentwash and control (water spray) during 2013 and 2014. The higher number of fruits per plant was observed during 2013 and 2014 (69.9 and 54.1, respectively) in T₁₂ treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution and it was on par with T₁₀ treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (T₁₀: 65.7, 53.2, respectively). The spentwash contained N, P, K, Ca, Mg and S and thus valued as a fertilizer when applied to soil through irrigation with water or through foliar spray. Similar results have been reported by Chandraju and Basavaraju (2007). The application of diluted spentwash increased the uptake of zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) in maize and wheat as compared to control and the highest total uptake of these were found at lower dilution levels than at higher dilution levels. The lowest (51.0 and 40.4, respectively) number of fruits per plant was recorded in T₁₃ [100% RDF + water sprays (5 times)] because of lesser nutrient availability.

Table 20. Effect of foliar application of diluted distillery spentwash on per cent fruit set and number of fruits per plant of tomato crop grown during 2013 and 2014

Treatments	Per cent fruit set			No. of fruits per plant		
	2013	2014	Pooled	2013	2014	Pooled
T₁	64.8	61.3	63.1	51.1	41.6	46.4
T₂	67.2	64.0	65.6	54.4	42.9	48.7
T₃	68.0	64.7	66.3	58.0	44.8	51.4
T₄	72.9	67.5	70.2	58.1	45.1	51.6
T₅	74.8	68.5	71.7	60.7	47.0	53.8
T₆	75.4	69.6	72.5	62.6	47.6	55.1
T₇	76.5	71.7	74.1	62.7	48.8	55.7
T₈	77.7	72.1	74.9	62.8	51.0	56.9
T₉	78.9	72.6	75.8	62.3	52.2	57.3
T₁₀	81.4	75.2	78.3	65.7	53.2	59.4
T₁₁	80.0	74.5	77.3	64.2	53.1	58.7
T₁₂	82.5	76.2	79.4	69.9	54.1	62.0
T₁₃	63.7	60.4	62.1	51.0	40.4	45.7
S. Em±	3.6	3.5	3.8	2.7	1.9	2.3
C. D. at 5%	10.5	10.2	10.7	7.8	5.4	6.6
CV (%)	8.4	8.74	9.1	7.6	6.7	7.5

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
 T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
 T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
 T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
 T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
 T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
 T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
 T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
 T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
 T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
 T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
 T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
 T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Pooled analysis of data of two years (2013 and 2014) revealed that the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher number of fruits per plant (62.0) which was on par with treatment T₁₀ receiving 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (59.4). However, significantly lower number of fruits per plant was observed in T₁₃ (45.7) which received 100% RDF + water sprays (5 times).

Weight of ten fruits (g)

The information on weight of ten fruits(g) at 2nd and 5th picking varied significantly but at 8th picking it did not differ significantly due to foliar application of diluted spentwash (Table 21).

Significantly higher weight of ten fruits (g) at 2nd and 5th picking (1448g and 1223g) was observed with the treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) compared to all the other treatments and was on par with treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (1430g and 1216g respectively) during 2013 at 2nd and 5th picking. The same trend was followed during 2014. This could be due to nutrients supplied through foliar application of diluted distillery spentwash. Significantly lower weight of ten fruits (1199g, 1062g and 877g, 892g) respectively were recorded during 2013 and 2014) in treatment T₁₃ which received 100% RDF + water sprays (5 times).

Pooled analysis of two years data of experiment showed significantly higher weight of ten fruits (g) at 2nd and 5th picking (1415g and 1203g, respectively) due to 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) and it was on par with 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (T₁₀: 1397g and 1191g, respectively) at 2nd and 5th picking. However, significantly lower (1131g and 884g, respectively) weight of ten fruits was observed in treatment T₁₃ which received 100% RDF + water sprays (5 times).

Fruit yield (kg plant⁻¹ and t ha⁻¹)

Foliar nutrition using diluted spentwash recorded a profound effect in increasing the fruit yield (kg plant⁻¹ and t ha⁻¹) during 2013 and 2014 (Table 22 and Fig.5). Higher yield was recorded due to foliar application of diluted distillery spentwash compared to undiluted spentwash and water spray. Higher fruit yield was recorded in the treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) (7.62, 6.54 kg plant⁻¹ and 84.4, 73.4 t ha⁻¹, respectively) followed by treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (T₁₀: 7.51, 6.45 kg plant⁻¹ and 83.1, 72.8 t ha⁻¹, respectively) Higher yield of tomato could be attributed to better total uptake of essential nutrients and its translocation to economic parts as well as improvement in yield attributing characters. These results are in conformity with the findings of Parameswari (2009).



Plate 4: General view of field experiment-I

Table 21. Effect of foliar application of diluted distillery spentwash on weight of ten fruits (g) at different pickings of tomato grown during 2013 and 2014

Treatments	At 2 nd picking			At 5 th picking			At 8 th picking		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	1300	1199	1250	943	936	939	751	612	681
T₂	1282	1237	1260	953	957	955	749	623	686
T₃	1332	1265	1298	1102	987	1045	757	637	697
T₄	1340	1273	1307	1039	992	1015	757	642	699
T₅	1322	1255	1288	1029	1002	1015	770	654	712
T₆	1403	1337	1370	1053	1003	1028	745	660	703
T₇	1395	1328	1362	1076	1023	1049	736	670	703
T₈	1408	1341	1375	1079	1029	1054	733	675	704
T₉	1412	1345	1379	1181	1131	1156	741	688	715
T₁₀	1430	1363	1397	1216	1166	1191	744	720	732
T₁₁	1418	1351	1384	1192	1140	1166	728	710	719
T₁₂	1448	1382	1415	1223	1183	1203	724	735	730
T₁₃	1199	1062	1131	877	892	884	741	542	642
S. Em±	40.0	57.2	48.8	39.5	40.2	39.1	51.8	49.9	51.2
C. D. at 5%	116.7	166.9	138.7	115.4	117.4	111.0	NS	NS	NS
CV (%)	5.1	7.7	6.4	6.4	6.7	6.4	12.0	13.1	12.6

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 22. Effect of foliar application of diluted distillery spentwash on fruit yield of tomato crop grown during 2013 and 2014.

Treatments	Fruit yield (kg plant ⁻¹)			Fruit yield (t ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled
T₁	5.51	5.00	5.31	61.2	56.0	58.6
T₂	5.74	5.22	5.42	63.0	57.4	60.2
T₃	6.23	5.34	5.73	68.7	58.9	63.8
T₄	6.32	5.45	5.84	69.8	59.7	64.8
T₅	6.65	5.62	6.10	73.3	62.3	67.8
T₆	6.92	5.83	6.46	76.8	62.6	69.7
T₇	7.01	6.14	6.54	77.4	67.4	72.4
T₈	7.23	6.11	6.61	80.1	67.5	73.8
T₉	7.32	6.20	6.73	80.8	68.3	74.6
T₁₀	7.51	6.45	6.94	83.1	72.8	77.9
T₁₁	7.30	6.32	6.82	80.9	71.2	76.0
T₁₂	7.62	6.54	7.14	84.4	73.4	78.9
T₁₃	5.22	4.83	5.02	57.4	54.1	55.7
S. Em±	0.3	0.2	0.3	4.0	2.9	3.4
C. D. at 5%	0.9	0.5	0.7	11.6	8.6	9.8
CV (%)	8.4	5.4	7.2	9.3	8.0	8.7

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
 T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
 T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
 T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
 T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
 T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
 T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
 T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
 T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
 T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
 T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
 T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
 T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

The tomato yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depend upon efficient photosynthetic structure as well as the extent of translocation into sink and also on plant growth and development during early stages of crop growth. The production and translocation of synthesized photosynthates depend upon mineral nutrients supplied either by soil or through foliar application. Most of the photosynthetic pathways are dependent on enzymes and coenzymes which are synthesized from mineral elements such as nitrogen, phosphorus and potassium. Nitrogen improves plant growth and productivity by having direct effect on the metabolism of plants. Nitrogen is usually applied through organic or inorganic sources. Hence, major nutrients play a vital role on the yield of crops.

However, significantly lower fruit yield both yield per plant and yield per ha (kg plant^{-1} and t ha^{-1}) during 2013 and 2014 was observed in treatment T_{13} ($5.22, 4.83 \text{ kg plant}^{-1}$ and $57.4, 54.1 \text{ t ha}^{-1}$, respectively) which received 100% RDF + water spray (5 times) and 100% RDF + 4 sprays of undiluted distillery spentwash (T_1) ($5.51, 5.0 \text{ kg plant}^{-1}$ and $61.2, 56.0 \text{ t ha}^{-1}$, respectively). This may be attributed to foliar application of undiluted distillery spentwash which caused accumulation of sodium and chloride salts in the root zone and leaves. This may result in reduced plant growth and yield. Similar observations were reported by Leth and Burrow (2002).

The results of pooled analysis of two years data (2013 and 2014) revealed that the treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T_{12}) recorded significantly higher fruit yield ($7.14 \text{ kg plant}^{-1}$ and 78.9 t ha^{-1} , respectively) when compared to 100% RDF + water sprays (5 times). (T_{13} : $5.02 \text{ kg plant}^{-1}$ and 55.7 t ha^{-1} , respectively) but it was on par with the treatment T_{10} receiving 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution ($6.94 \text{ kg plant}^{-1}$ and 77.9 t ha^{-1} , respectively).

4.4.3 Quality parameters

The data pertaining to quality parameters such as total soluble sugars (TSS), ascorbic acid and lycopene content of tomato crop as influenced by foliar application of diluted distillery spentwash during 2013 and 2014 are presented in Table 23 and Fig 6.

TSS ($^{\circ}\text{Brix}$)

Significantly higher TSS value was observed during 2013 and 2014 in the treatment T_{12} receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (6.1 and 5.7°Brix , respectively). However, it was on par with the application of 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (T_{10} : 5.8 and 5.3°Brix , respectively), 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution (T_{11} : 5.8 and 5.3°Brix , respectively), 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution (T_9 : 5.7 and 5.2°Brix , respectively). This could be due to the presence of appreciable quantities of potassium (K), sulphur (S), nitrogen (N), phosphorous (P) as well as easily biodegradable organic matter in primary treated distillery spentwash and its application through foliar spray resulted in improvement in the quality of

tomato crop. Further, significantly lower TSS value was observed in treatment receiving 100% RDF + water sprays (5 times) during 2013 and 2014 (T_{13} : 4.6 and 4.3 °Brix, respectively). This is because of plant nutrients are present in very minimum quantity in water.

Pooled analysis of two years data of experiment recorded significantly higher TSS value (5.9 °Brix) in T_{12} treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution followed by T_{10} receiving 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (5.6 °Brix). However, significantly lower TSS value was observed in T_{13} (4.5 °Brix) which received 100% RDF + water sprays (Table 23).

Ascorbic acid ($\text{mg } 100^{-1} \text{ g}$)

The results pertaining to the effect of foliar application of diluted spentwash on the ascorbic acid content of tomato are presented in Table 23. Significant increase in the ascorbic acid content of tomato fruits was recorded with the application of diluted spentwash over undiluted spentwash and control during 2013 and 2014. The ascorbic acid content of tomato was higher (56.7 and 51.6 $\text{mg } 100^{-1} \text{ g}$, respectively) in T_{12} treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution and was on par with T_{10} treatment receiving 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (54 and 50.0 $\text{mg } 100^{-1}$, respectively) during 2013 and 2014. This might be due to the fact that at lower dilution more nutrients are supplied at optimum level as compared to higher dilution levels. Srinivasamurthy *et al.* (2006) reported that every cubic meter of distillery spentwash contains 1kg of nitrogen, 0.2kg of phosphorus and 10kg of potassium, most of these nutrients are in soluble form and are easily available to plants. Diluted spentwash act as dilute liquid organic fertilizer with high K content and potassium play a major role in improving the quality of tomato. Kulkarni *et al.* (1987) observed that N was mostly in colloid form behaving as a slow release fertilizer better than most inorganic N sources

The ascorbic acid content was lower (44.2 and 38.6 $\text{mg } 100^{-1}$, respectively) in T_{13} [100% RDF + water sprays (5 times)] and undiluted distillery spentwash (45.1 and 39.8 $\text{mg } 100^{-1}$, respectively) during 2013 and 2014. This could be due to high concentration of soluble salts being applied to tomato crop through undiluted distillery spentwash in foliar application leading to reduction in ascorbic acid synthesis.

Pooled analysis of data of two years (2013 and 2014) revealed that the treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T_{12}) recorded significantly higher ascorbic acid (54.2 $\text{mg } 100^{-1}$). However, significantly lower ascorbic acid was observed in T_{13} (41.4 $\text{mg } 100^{-1}$) which received 100% RDF + water sprays (5 times).

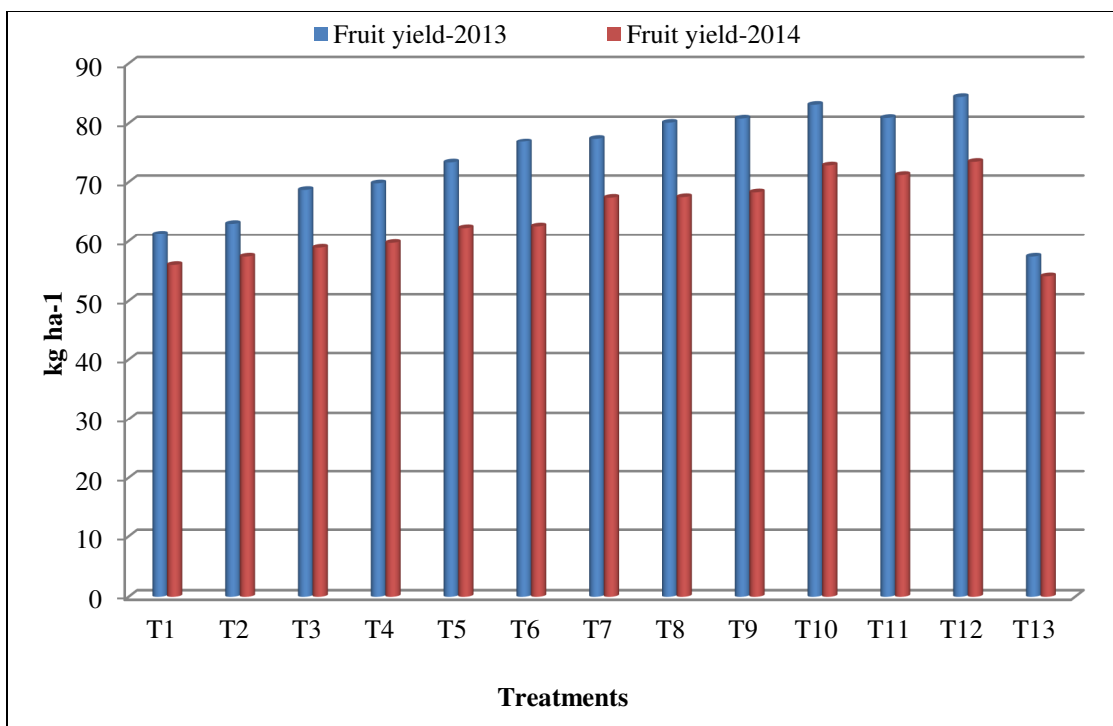


Fig. 5: Fruit yield of tomato grown during 2013 and 2014 as influenced by foliar application of diluted distillery spentwash

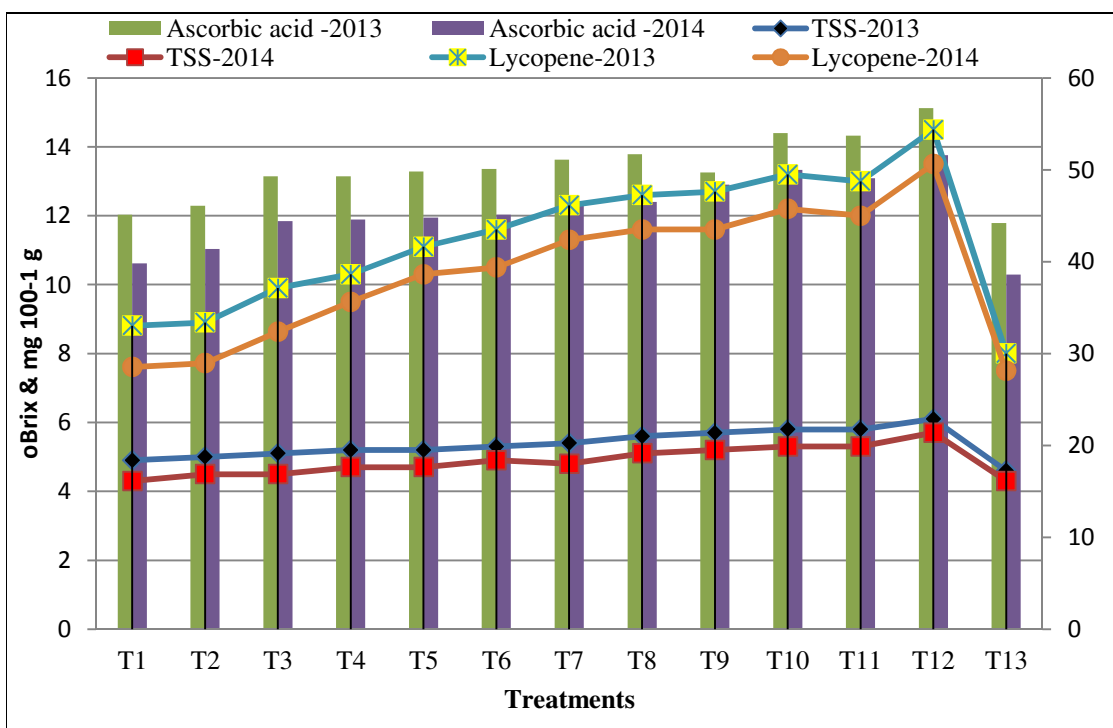


Fig. 6: Quality parameters of tomato grown during 2013 and 2014 as influenced by foliar application of diluted distillery spentwash

Table 23. Effect of foliar application of diluted distillery spentwash on TSS, ascorbic acid and lycopene content of tomato grown during 2013 and 2014.

Treatments	TSS ($^{\circ}$ Brix)			Ascorbic acid (mg 100 ⁻¹ g)			Lycopene (mg 100 ⁻¹ g)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	4.9	4.3	4.6	45.1	39.8	42.4	8.81	7.61	8.25
T₂	5.0	4.5	4.8	46.1	41.4	43.8	8.90	7.72	8.32
T₃	5.1	4.5	4.8	49.3	44.4	46.9	9.90	8.63	9.34
T₄	5.2	4.7	5.0	49.3	44.6	47.0	10.3	9.50	9.93
T₅	5.2	4.7	5.0	49.8	44.8	47.3	11.1	10.3	10.7
T₆	5.3	4.9	5.1	50.1	45.1	47.6	11.6	10.5	11.0
T₇	5.4	4.8	5.1	51.1	46.2	48.7	12.3	11.3	11.8
T₈	5.6	5.1	5.4	51.7	46.5	49.1	12.6	11.6	12.1
T₉	5.7	5.2	5.5	49.7	48.4	49.1	12.7	11.6	12.2
T₁₀	5.8	5.3	5.6	54.0	50.0	52.0	13.2	12.2	12.7
T₁₁	5.8	5.3	5.6	53.7	49.1	51.4	13.0	12.0	12.5
T₁₂	6.1	5.7	5.9	56.7	51.6	54.2	14.5	13.5	14.0
T₁₃	4.6	4.3	4.5	44.2	38.6	41.4	8.0	7.5	7.8
S. Em\pm	0.2	0.2	0.2	2.2	2.3	2.3	0.5	0.5	0.5
C. D. at 5%	0.7	0.7	0.6	6.5	6.8	6.4	1.4	1.3	1.3
CV (%)	7.2	8.2	7.5	7.7	8.9	8.2	7.2	7.7	7.3

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Lycopene (mg 100⁻¹ g)

Foliar application of distillery spentwash of different dilutions showed a profound effect in increasing the lycopene content of tomato (mg 100⁻¹ g) during 2013 and 2014. Higher lycopene content was recorded in the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (14.5 and 13.5mg 100⁻¹ g, respectively) followed by treatment T₁₀ which received 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (13.2 and 12.2mg 100⁻¹ g, respectively). This could be due to manurial effect of distillery spentwash. Distillery spentwash contains appreciable amount of nutrients especially potassium, which plays a vital role in quality improvement in tomato and also potassium is very important in the overall metabolism of plant. In addition, it has a beneficial effect on maintenance of internal water level and involved in a number of steps in protein synthesis. whereas, potassium is involved in maintenance of ionic balance in cells and it bounds ionically to the enzyme pyruvate kinase, which is essential in carbohydrates metabolism (Marchener, 1995).

However, significantly lower lycopene content was observed in T₁₃ (8.0 and 7.5 mg 100⁻¹ g, respectively) which received 100% RDF + water sprays (5 times) and 100% RDF + sprays of undiluted distillery spentwash (T₁) (8.81 and 7.61 mg 100⁻¹ g, respectively). This could be due to the scorching effect of higher concentration of soluble salts and total dissolved solids present in undiluted distillery spentwash.

The results of pooled analysis of data of two years (2013 and 2014) revealed that the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher lycopene content of tomato (14.0mg 100⁻¹ g) compared to all the other treatments. However, significantly lower lycopene content was observed in treatment T₁₃ which received 100% RDF + water sprays (5 times) (7.8 mg 100⁻¹ g).

4.4.4 Nutrient concentration of whole tomato plant at 80 DAT

The data on concentration of nitrogen, phosphorus and potassium in tomato plant varied significantly due to foliar application of diluted distillery spentwash during 2013 and 2014 at 80 days after transplanting.

The concentration of nitrogen, phosphorus and potassium were higher in tomato crop grown during 2013 compared to 2014 (Table 24). Nitrogen, phosphorus and potassium concentration in tomato crop was significantly higher in T₁₂ treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (N: 2.38, 2.00 %, P: 0.62, 0.51% and K: 2.68, 2.10 %, respectively) compared to all the other treatments during 2013 and 2014. However, lower nitrogen, phosphorus and potassium concentration was noticed in treatment T₁₃ receiving 100% RDF + water sprays (5 times) (N: 1.86, 1.56 %, P: 0.39, 0.31% and K: 2.20, 1.68 %, respectively) and treatment T₁ which received foliar application of undiluted distillery spentwash (N: 1.92, 1.62 %, P: 0.41, 0.33% and K: 2.21, 1.71 %, respectively) during 2013 and 2014.

Table 24. Effect of foliar application of diluted distillery spentwash on primary nutrients content (at 80 DAT) in whole tomato plant grown during 2013 and 2014.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	1.92	1.62	1.77	0.41	0.33	0.37	2.21	1.71	1.96
T₂	1.95	1.65	1.80	0.45	0.33	0.39	2.22	1.72	1.97
T₃	2.01	1.68	1.85	0.48	0.34	0.41	2.28	1.76	2.02
T₄	2.05	1.70	1.88	0.51	0.35	0.43	2.31	1.80	2.06
T₅	2.11	1.70	1.91	0.55	0.38	0.47	2.35	1.83	2.09
T₆	2.18	1.72	1.95	0.56	0.39	0.49	2.38	1.92	2.15
T₇	2.22	1.74	1.98	0.57	0.41	0.51	2.45	1.89	2.17
T₈	2.27	1.79	2.03	0.59	0.45	0.54	2.47	1.92	2.20
T₉	2.31	1.82	2.07	0.60	0.47	0.56	2.52	1.92	2.22
T₁₀	2.32	1.95	2.14	0.61	0.50	0.56	2.62	2.07	2.35
T₁₁	2.31	1.88	2.10	0.58	0.48	0.53	2.52	1.94	2.23
T₁₂	2.38	2.00	2.19	0.62	0.51	0.57	2.68	2.10	2.39
T₁₃	1.86	1.56	1.71	0.39	0.31	0.35	2.20	1.68	1.94
S. Em±	0.03	0.02	0.03	0.02	0.02	0.02	0.05	0.03	0.04
C. D. at 5%	0.08	0.07	0.07	0.07	0.07	0.07	0.14	0.10	0.12
CV (%)	2.3	2.3	2.3	7.7	10.1	8.6	3.4	3.2	3.3

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Pooled analysis of data of two years (2013 and 2014) revealed that, the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher concentration (N: 2.19 %, P: 0.57 % and K: 2.39 %, respectively) of nitrogen, phosphorus and potassium. However, significantly lower concentration of nitrogen, phosphorus and potassium was observed in T₁₃ (N: 1.71 %, P: 0.35% and K: 1.94 %, respectively) which received 100% RDF + water sprays (5 times).

The data on concentration of calcium, magnesium and sulphur in whole tomato plant varied significantly due to foliar application of diluted distillery spentwash (Table 25).

The concentration of calcium, magnesium and sulphur decreased in whole tomato plant during 2014 compared to 2013.

The data pertaining to concentration of calcium, magnesium and sulphur in whole tomato plant differed significantly due to foliar application of diluted distillery spentwash at 80 days after transplanting (Table 25). Application of 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) recorded significantly higher concentration of calcium, magnesium and sulphur (Ca: 0.62, 0.56 %, Mg: 0.40, 0.34 % and S: 0.45, 0.40 %, respectively) in whole tomato plant compared to all the other treatments and it was on par with treatment T₁₀ which received 100 % RDF + 5 sprays of distillery spentwash at 1:4 dilution and the values are Ca: 0.60, 0.52 %, Mg: 0.39, 0.33 % and S: 0.43, 0.39 %, respectively. Significantly lower concentration of calcium, magnesium and sulphur in whole tomato plant (Ca: 0.40, 0.28 %, Mg: 0.20, 0.11 % and S: 0.17, 0.10 %, respectively) were observed in the treatment T₁₃ which received 100% RDF + water sprays (5 times).

Pooled analysis of two years experiment data showed that the Ca, Mg and S concentration in whole tomato plant varied significantly due to treatments at 80 days after transplanting. Higher concentration of Ca, Mg and S was observed in the treatment T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (0.59, 0.37 and 0.43 %, respectively) compared to other treatments. Significantly lower concentration (0.34, 0.16 and 0.14 %, respectively) was recorded in the treatment T₁₃ which received 100% RDF + water sprays (5 times).

The concentration of micronutrients in whole tomato plant as influenced by foliar application of diluted distillery spentwash at 80 days after transplanting is presented in Table 26.

The concentration of all the micronutrients was higher in whole tomato plant grown during 2013 compared to 2014. However, significantly higher concentration of Fe, Mn, Zn, Cu and B were observed in treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (662.2, 372.6, 72.0, 16.4, 11.8 mg kg⁻¹ and 610.2, 310.2, 70.0, 15.5 11.0 mg kg⁻¹, respectively) compared to all other treatments during 2013 and 2014. However, lower Zn, B, Fe, Mn and Cu contents were recorded in treatment T₁₃ which received 100% RDF + water spray (465.2, 226.7, 48.6, 10.2, 8.1 mg kg⁻¹ and 450.2, 165.5, 24.0, 9.1, 8.0 mg kg⁻¹, respectively) during 2013 and 2014.

Table 25. Effect of foliar application of diluted distillery spentwash on secondary nutrients content (at 80 DAT) in whole tomato plant grown during 2013 and 2014.

Treatments	Calcium (%)			Magnesium (%)			Sulphur (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	0.42	0.30	0.36	0.19	0.13	0.16	0.23	0.17	0.20
T₂	0.43	0.32	0.38	0.20	0.15	0.18	0.25	0.20	0.23
T₃	0.46	0.35	0.41	0.22	0.17	0.20	0.27	0.23	0.25
T₄	0.48	0.36	0.42	0.24	0.20	0.22	0.28	0.26	0.27
T₅	0.51	0.41	0.46	0.25	0.22	0.24	0.31	0.28	0.30
T₆	0.52	0.43	0.48	0.27	0.26	0.27	0.33	0.30	0.32
T₇	0.53	0.49	0.51	0.29	0.25	0.27	0.35	0.31	0.33
T₈	0.55	0.42	0.49	0.32	0.27	0.30	0.36	0.33	0.35
T₉	0.57	0.45	0.51	0.35	0.30	0.33	0.38	0.35	0.37
T₁₀	0.60	0.52	0.56	0.39	0.33	0.36	0.43	0.39	0.41
T₁₁	0.58	0.48	0.53	0.38	0.31	0.35	0.40	0.37	0.39
T₁₂	0.62	0.56	0.59	0.40	0.34	0.37	0.45	0.40	0.43
T₁₃	0.40	0.28	0.34	0.20	0.11	0.16	0.17	0.10	0.14
S. Em±	0.04	0.02	0.03	0.01	0.02	0.02	0.01	0.02	0.02
C. D. at 5%	0.12	0.07	0.09	0.03	0.07	0.06	0.04	0.07	0.06
CV (%)	13.4	9.9	12.1	6.1	17.6	14.6	6.9	14.1	12.0

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
 T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
 T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
 T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
 T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
 T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
 T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
 T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
 T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
 T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
 T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
 T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
 T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 26. Effect of foliar application of diluted distillery spentwash on micronutrients content (at 80 DAT) in whole tomato plant grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(mg kg ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	201	Pooled	2013	201	Pooled
T ₁	529.3	496.2	512.8	260.0	174.6	217.3	50.3	32.0	41.1	11.5	10.4	11.0	8.8	7.7	8.2
T ₂	534.2	510.2	522.2	270.0	181.2	225.6	52.3	35.0	43.6	11.7	10.6	11.2	9.0	8.8	8.9
T ₃	546.2	525.9	536.1	277.0	197.2	237.1	55.7	37.0	46.3	12.6	11.6	12.1	9.1	9.0	9.1
T ₄	559.5	532.9	546.2	297.4	207.6	252.5	58.3	39.0	48.7	12.9	11.8	12.4	9.3	9.2	9.3
T ₅	576.2	542.1	559.2	305.2	217.6	261.4	60.2	45.0	52.6	13.2	12.1	12.7	9.5	9.3	9.4
T ₆	586.2	558.2	572.2	310.2	222.6	266.4	63.0	47.0	55.0	13.3	12.9	13.1	9.7	9.0	9.3
T ₇	602.3	568.9	585.6	316.2	241.3	278.8	65.0	47.0	56.0	13.6	13.5	13.6	10.0	10.1	10.0
T ₈	614.2	571.2	592.7	318.2	255.8	287.0	68.0	50.0	59.0	14.5	14.4	14.5	10.1	10.2	10.2
T ₉	624.5	583.2	603.9	333.2	271.6	302.4	66.8	54.0	60.4	15.8	14.7	15.3	10.6	10.4	10.5
T ₁₀	646.2	601.5	623.9	362.5	300.2	331.4	68.5	67.0	67.8	16.3	15.1	15.7	11.2	10.2	10.7
T ₁₁	634.5	598.3	616.4	340.2	287.6	313.9	67.1	62.0	64.6	15.8	14.8	15.3	10.8	10.7	10.7
T ₁₂	662.2	610.2	636.2	372.6	310.2	341.4	72.0	70.0	71.0	16.4	15.5	16.0	11.8	11.0	11.4
T ₁₃	465.2	450.2	457.7	226.7	165.5	196.1	48.6	24.0	36.3	10.2	9.1	9.7	8.1	8.0	8.0
S. Em±	27.74	27.97	23.68	16.0	17.3	16.37	2.36	2.36	2.31	0.52	0.52	0.51	0.30	0.57	0.28
C. D. at 5%	80.96	81.63	69.1	46.8	50.4	46.5	6.88	6.88	6.56	1.51	1.51	1.44	0.85	1.60	0.82
CV (%)	8.24	8.81	7.24	9.04	12.84	10.5	6.7	8.7	7.4	6.7	6.8	6.6	5.15	10.4	5.06

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

4.4.5 Nutrient uptake by tomato plant at 80 DAT

The nitrogen, phosphorus and potassium uptake by whole tomato plant differed significantly due to foliar application of diluted distillery spentwash at 80 days after transplanting (Table 27).

The nitrogen, phosphorus and potassium uptake by whole tomato plant at 80 days after transplanting was lower during 2014 compared to 2013. Significantly higher nitrogen, phosphorus and potassium uptake by whole tomato plant at 80 days after transplanting was recorded in the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution during 2013 and 2014 (N: 113.4, 82.9, P: 29.6, 21.1 and K: 127.7, 87.1 kg ha⁻¹, respectively). However, lower nitrogen, phosphorus and potassium uptake by whole tomato plant was recorded in the treatment T₁₃ which received 100% RDF + water spray (N: 64.8, 44.4, P: 13.6, 8.8 and K: 76.7, 47.8 kg ha⁻¹, respectively) and treatment T₁ which received 4 sprays of undiluted distillery spentwash (N: 71.3, 50.7, P: 15.2, 10.3 and K: 82.1, 53.5 kg ha⁻¹, respectively) during 2013 and 2014.

Results of pooled analysis of data of two years (2013 and 2014) significantly indicate that higher nitrogen, phosphorus and potassium uptake by whole tomato plant at 80 days after transplanting (98.2, 25.3 and 107.4 kg ha⁻¹, respectively) was noticed in the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution. It was on par with T₁₀ which received 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (93.8, 24.4 and 103.3 kg ha⁻¹). However, significantly lower nitrogen, phosphorus and potassium uptake by whole tomato plant was noticed in treatment T₁₃ which received 100% RDF + water sprays (5 times) (T₁₃: 54.6, 11.2 and 62.3 kg ha⁻¹, respectively).

The data on uptake of calcium, magnesium and sulphur by whole tomato plant at 80 days after transplanting was found to differ significantly due to foliar application of diluted distillery spentwash (Table 28).

Uptake of calcium, magnesium and sulphur by whole tomato plant was lower during 2014 compared to 2013. Higher uptake of calcium, magnesium and sulphur by whole tomato plant was recorded in treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (29.6, 19.1, 21.4 kg ha⁻¹ and 23.2, 14.1, 16.6 kg ha⁻¹) during 2013 and 2014 respectively. However, lower uptake of calcium, magnesium and sulphur (13.9, 7.0, 5.9 kg ha⁻¹ and 8.0, 3.1, 2.8 kg ha⁻¹, respectively) was recorded in the control.

The results of pooled analysis of data for two years (2013 and 2014) revealed that 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) recorded significantly higher uptake of Ca, Mg and S (26.4, 16.6 and 19.0 kg ha⁻¹, respectively) by whole tomato plant compared to all the other treatments and was on par with treatment T₁₀ receiving 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (24.6, 15.8 and 18.0 kg ha⁻¹, respectively). However, significantly lower uptake of Ca, Mg and S by whole tomato plant (11.0, 5.1 and 4.4 kg ha⁻¹, respectively) was observed in the treatment T₁₃ which received 100% RDF + water sprays (5 times).

Table 27. Effect of foliar application of diluted distillery spentwash on primary nutrients uptake (at 80 DAT) by whole tomato crop grown during 2013 and 2014

Treatments	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	71.3	50.7	61.0	15.2	10.3	12.8	82.1	53.5	67.8
T₂	72.3	51.0	61.7	16.7	10.2	13.4	82.3	53.2	67.8
T₃	76.6	54.0	65.3	18.3	10.9	14.6	86.9	56.6	71.7
T₄	84.3	59.3	71.8	21.0	12.2	16.6	95.0	62.8	78.9
T₅	85.9	58.8	72.4	22.4	13.2	17.8	95.7	63.3	79.5
T₆	89.6	60.0	74.8	23.8	13.6	18.7	97.9	64.5	81.2
T₇	90.9	60.2	75.5	24.6	14.2	19.4	100.3	65.4	82.8
T₈	94.9	64.0	79.4	26.3	16.1	21.2	103.3	68.6	85.9
T₉	102.2	68.9	85.5	28.8	17.8	23.3	111.5	72.6	92.1
T₁₀	108.9	78.7	93.8	28.6	20.2	24.4	123.0	83.6	103.3
T₁₁	103.4	72.7	88.0	26.0	18.6	22.3	112.8	75.0	93.9
T₁₂	113.4	82.9	98.2	29.6	21.1	25.3	127.7	87.1	107.4
T₁₃	64.8	44.4	54.6	13.6	8.8	11.2	76.7	47.8	62.3
S. Em±	5.73	4.61	5.14	1.49	1.15	1.30	6.36	4.84	5.57
C. D. at 5%	16.72	13.45	15.01	4.36	3.34	3.81	18.56	14.12	16.27
CV (%)	11.1	12.9	11.79	11.4	13.8	12.18	11.1	12.8	11.68

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 28. Effect of foliar application of diluted distillery spentwash on secondary nutrients uptake (at 80 DAT) by whole tomato crop grown during 2013 and 2014.

Treatments	Calcium (kg ha ⁻¹)			Magnesium (kg ha ⁻¹)			Sulphur (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	15.6	9.4	12.5	8.2	4.7	6.4	7.1	4.1	5.6
T₂	15.9	9.9	12.9	8.9	5.3	7.1	7.4	4.7	6.0
T₃	17.5	11.3	14.4	9.9	6.1	8.0	8.4	5.6	6.9
T₄	19.7	12.6	16.2	12.3	8.1	10.2	9.9	7.0	8.5
T₅	20.8	14.2	17.5	12.6	9.0	10.8	10.6	7.62	9.1
T₆	21.4	15.0	18.2	13.6	9.8	11.7	11.5	9.13	10.3
T₇	21.7	17.0	19.3	13.9	9.3	11.6	13.1	10.0	11.6
T₈	23.0	15.0	19.0	14.6	10.0	12.3	14.6	11.8	13.2
T₉	25.2	17.0	21.1	16.4	11.3	13.9	16.8	13.2	15.0
T₁₀	28.2	21.0	24.6	18.8	12.9	15.8	20.2	15.7	18.0
T₁₁	26.0	18.6	22.3	17.0	12.0	14.5	17.9	14.3	16.1
T₁₂	29.6	23.2	26.4	19.1	14.1	16.6	21.4	16.6	19.0
T₁₃	13.9	8.0	11.0	7.0	3.1	5.1	5.9	2.8	4.4
S. Em±	1.41	1.22	1.30	0.89	0.77	0.82	0.89	0.89	0.87
C. D. at 5%	4.11	3.55	3.78	2.60	2.25	2.38	2.60	2.59	2.53
CV (%)	11.4	14.3	12.4	11.6	15.0	12.77	12.2	16.4	13.6

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash

T₂: 100% RDF + 5 sprays of undiluted distillery spentwash

T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1dilution

T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution

T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution

T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution

T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution

T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution

T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution

T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution

T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution

T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution

T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

The results on uptake of Fe, Mn, Zn, Cu and B by whole tomato plant at 80 days after transplanting varied significantly due to foliar application of diluted distillery spentwash (Table 29).

The concentration and uptake of micronutrients by whole tomato plant was lower during 2014 compared to 2013. Higher uptake of Fe, Mn, Zn, Cu and B were recorded in treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (3156, 1775.9, 333.6, 73.9, 56.2 g ha⁻¹ and 2529, 1285.9, 298.5, 68.0, 45.6, g ha⁻¹) compared to all the other treatments during 2013 and 2014 respectively. However, lower uptake of Fe, Mn, Zn, Cu and B (1621, 790.1, 169.4, 35.6, 28.2 g ha⁻¹ and 1282, 471.2, 68.3, 26.0, 22.7 g ha⁻¹, respectively) was observed in the treatment T₁₃ which received water spray.

Pooled analysis of data of two years (2013 and 2014) showed significantly higher uptake of Fe, Mn, Zn, Cu and B by whole tomato plant in the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (2843, 1530.9, 316, 70.9, 50.9 g ha⁻¹) that was on par with 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (2731, 1456.7, 296, 68.3, 48.2 g ha⁻¹, respectively). Lower uptake of Fe, Mn, Zn, Cu and B by whole tomato plant was observed in the control (1452, 630.7, 118.9, 30.8, 25.4 g ha⁻¹, respectively).

Significantly higher concentration and uptake of nutrients was observed in respect of the cations (Ca, Mg and K) and anions (N, P and S) by the whole tomato crop at 80 DAT during 2013 and 2014 due to foliar application of diluted distillery spentwash (Table 24 to 29). Significantly higher concentration and uptake of all the nutrients was recorded in treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution and it was on par with T₁₀ which received 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution. Such improvements were possibly due to the enhanced biomass of the crop, there by increased concentration and uptake of cations and anions. Diluted distillery spentwash contains some amounts of nutrients, which are in the soluble form and easily available to plants. Chandraju and Basavaraju (2007) reported that distillery spentwash could be used as a complement to mineral fertilizer to crops. The spentwash contained N, P, K, Ca, Mg and S and thus valued as a fertilizer when applied either through soil or foliar application along with water. The application of diluted spentwash increased the uptake of zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) by maize and wheat as compared to control and the highest total uptake of these nutrients were found at lower dilution levels than at higher dilution levels. However, significantly lower concentration and uptake of cations and anions were observed in the treatment T₁₃ which received 100% RDF + water spray and treatment T₁ which received 4 sprays of undiluted distillery spentwash during both years. This may be due to toxic effect of the soluble salts present in undiluted distillery spentwash resulted in decrease in the availability of nutrients to the crop.

These findings are in accordance with Parameswari (2009) and Prabakaran (2003) who reported that the essential nutrients like Ca, Mg, P and K were increased in maize, sunflower, sugarcane, tomato and fodder grass under treated effluent irrigation.

Table 29. Effect of foliar application of diluted distillery spentwash on micronutrients uptake (at 80 DAT) by whole tomato crop grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc (g ha ⁻¹)			Copper			Boron		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	1967	1553	1760	966.0	546.5	756.2	186.7	100.2	143.4	42.7	32.6	37.7	32.8	23.9	28.4
T ₂	1981	1578	1780	1001.2	560.6	780.9	193.7	108.3	151.0	43.4	32.9	38.1	33.2	27.1	30.1
T ₃	2081	1699	1890	1055.2	634.3	844.7	212.0	119.0	165.5	48.0	37.3	42.7	34.7	29.0	31.9
T ₄	2301	1860	2080	1221.5	724.6	973.0	239.8	136.1	187.9	53.1	41.2	47.1	38.2	32.1	35.2
T ₅	2347	1876	2111	1243.0	753.0	998.0	245.3	155.7	200.5	53.8	41.9	47.8	38.5	32.3	35.4
T ₆	2410	1947	2179	1275.5	776.4	1026.0	259.0	163.9	211.5	54.7	45.0	49.8	39.8	33.7	36.7
T ₇	2465	1969	2217	1294.1	835.3	1064.7	266.0	162.7	214.4	55.7	46.7	51.2	40.8	35.0	37.9
T ₈	2568	2042	2305	1330.2	914.3	1122.2	284.3	178.7	231.5	60.6	51.5	56.0	42.3	36.6	39.5
T ₉	2763	2206	2485	1474.2	1027.5	1250.9	295.6	204.3	249.9	65.0	59.8	62.4	46.8	39.4	43.1
T ₁₀	3033	2429	2731	1701.2	1212.1	1456.7	321.5	270.5	296.0	70.9	65.8	68.3	52.6	43.8	48.2
T ₁₁	2839	2314	2576	1522.3	1112.1	1317.2	300.3	239.7	270.0	66.2	61.1	63.7	48.3	41.2	44.8
T ₁₂	3156	2529	2843	1775.9	1285.9	1530.9	333.6	298.5	316.0	73.9	68.0	70.9	56.2	45.6	50.9
T ₁₃	1621	1282	1452	790.1	471.2	630.7	169.4	68.3	118.9	35.6	26.0	30.8	28.2	22.7	25.4
S. Em±	156.8	144.4	149.8	84.0	68.9	75.6	16.56	15.46	15.68	3.62	3.73	3.64	2.66	2.57	2.60
C. D. at 5%	457.8	421.6	437.4	245.2	201.1	220.5	48.34	45.11	45.77	10.57	10.90	10.62	7.77	7.50	7.59
CV (%)	11.2	12.9	11.9	11.4	14.3	12.37	11.3	15.8	12.81	11.3	13.8	12.29	11.2	13.1	12.01

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Similarly micro-nutrients concentration and uptake was also found to be higher due to foliar application of 1:5 diluted distillery spentwash compared to all the other treatments. Higher nutrient concentration and uptake was due to treatment involving foliar application of diluted distillery spentwash, plants absorb 30-40% of spray solution at the time of foliar application and the remaining spray solution drops on to soil surface and thus improves soil physical and chemical conditions that might have increased the availability of nutrients. The increase in uptake of nutrients may also be due to nutrient content coupled with better vegetative growth in these treatments. Results of enhanced uptake of nutrients due to the application of raw spentwash was reported by Gomez (1996) and Mahendra (2007).

4.4.6 Nutrient concentration in tomato fruits at harvest

The concentration of nitrogen, phosphorus and potassium in tomato fruits varied significantly due to foliar application of diluted distillery spentwash at harvest (Table 30). The concentration of nitrogen, phosphorus and potassium was higher in tomato fruit grown during 2013 compared to 2014.

Nitrogen, phosphorus and potassium concentration in tomato fruit was significantly higher in T₁₂ treatment which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (2.34, 0.31, 2.89 % and 2.00, 0.27, 2.57 %) compared to all the other treatments during 2013 and 2014, respectively. However, lower nitrogen, phosphorus and potassium concentration was noticed in treatment T₁₃ which received 100% RDF + water sprays (5 times) (2.14, 0.19, 2.47 and 1.80, 0.15, 2.15 %) during 2013 and 2014, respectively.

The pooled analysis of two years data revealed that the concentration of N, P and K in tomato fruit was significantly higher in the treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (2.17, 0.29 and 2.73 %, respectively). Significantly lower concentration of N, P and K was recorded in the treatment T₁₃ which received 100% RDF + water sprays (5 times) (1.97, 0.17 and 2.31 %, respectively).

The data presented in Table 31 revealed that the concentration of calcium, magnesium and sulphur in tomato fruit varied significantly due to foliar application of diluted distillery spentwash at harvest. The concentration of calcium, magnesium and sulphur was higher in tomato fruit during 2013 than 2014.

Pooled analysis of two years data indicated that the Ca, Mg and S concentration in tomato fruit varied significantly due to treatments. Higher concentration of Ca, Mg and S was observed in the treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (0.44, 0.28 and 0.38 %, respectively) compared to other treatments. Significantly lower concentration was recorded in the treatment T₁₃ which received 100% RDF + water sprays (5 times) (0.24, 0.11 and 0.19 %, respectively). Similar trend was observed during 2013 and 2014.

Table 30. Effect of foliar application of diluted distillery spentwash on primary nutrients content at harvest of tomato fruit grown during 2013 and 2014.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	2.16	1.81	1.99	0.20	0.16	0.18	2.52	2.20	2.36
T₂	2.18	1.84	2.01	0.23	0.19	0.21	2.57	2.25	2.41
T₃	2.20	1.86	2.03	0.24	0.20	0.22	2.62	2.30	2.46
T₄	2.21	1.87	2.04	0.25	0.21	0.23	2.73	2.34	2.53
T₅	2.25	1.91	2.08	0.26	0.22	0.24	2.71	2.39	2.55
T₆	2.22	1.88	2.05	0.27	0.23	0.25	2.75	2.43	2.59
T₇	2.25	1.91	2.08	0.28	0.24	0.26	2.80	2.48	2.64
T₈	2.30	1.96	2.13	0.30	0.26	0.28	2.82	2.50	2.66
T₉	2.28	1.94	2.11	0.28	0.24	0.26	2.86	2.54	2.70
T₁₀	2.30	1.96	2.13	0.30	0.26	0.28	2.85	2.53	2.69
T₁₁	2.31	1.97	2.14	0.31	0.27	0.29	2.82	2.50	2.66
T₁₂	2.34	2.00	2.17	0.31	0.27	0.29	2.89	2.57	2.73
T₁₃	2.14	1.80	1.97	0.19	0.15	0.17	2.47	2.15	2.31
S. Em±	0.02	0.03	0.02	0.02	0.02	0.02	0.05	0.03	0.02
C. D. at 5%	0.06	0.08	0.06	0.06	0.05	0.05	0.15	0.10	0.06
CV (%)	1.7	2.6	1.8	14.3	12.7	13.5	3.3	2.5	1.4

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 31. Effect of foliar application of diluted distillery spentwash on secondary nutrients content at harvest of tomato fruit grown during 2013 and 2014.

Treatments	Calcium (%)			Magnesium (%)			Sulphur (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	0.31	0.22	0.27	0.16	0.10	0.13	0.25	0.17	0.21
T₂	0.35	0.24	0.30	0.17	0.12	0.15	0.26	0.18	0.22
T₃	0.38	0.26	0.32	0.18	0.13	0.16	0.27	0.19	0.23
T₄	0.39	0.26	0.33	0.19	0.15	0.17	0.28	0.21	0.25
T₅	0.40	0.28	0.34	0.21	0.17	0.19	0.29	0.23	0.26
T₆	0.42	0.29	0.36	0.23	0.18	0.21	0.31	0.24	0.28
T₇	0.43	0.30	0.37	0.24	0.19	0.22	0.34	0.26	0.30
T₈	0.44	0.32	0.38	0.25	0.21	0.23	0.35	0.28	0.32
T₉	0.45	0.35	0.40	0.27	0.22	0.25	0.36	0.30	0.33
T₁₀	0.47	0.37	0.42	0.29	0.24	0.27	0.37	0.33	0.35
T₁₁	0.46	0.36	0.41	0.28	0.23	0.26	0.38	0.32	0.35
T₁₂	0.48	0.39	0.44	0.30	0.26	0.28	0.41	0.35	0.38
T₁₃	0.26	0.21	0.24	0.13	0.08	0.11	0.23	0.15	0.19
S. Em±	0.03	0.02	0.03	0.01	0.02	0.02	0.03	0.02	0.03
C. D. at 5%	0.10	0.05	0.08	0.03	0.05	0.06	0.08	0.06	0.10
CV (%)	14.9	10.3	13.46	7.46	13.24	14.32	15.65	14.60	16.02

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

The concentration of micronutrients in tomato fruit as influenced by foliar application of diluted distillery spentwash at harvest is presented in Table 32. The concentration of all the micronutrients was higher in tomato fruit grown during 2013 over 2014.

Significantly higher concentration of Fe, Mn, Zn, Cu and B were observed in treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (538.3, 199.5, 61.3, 14.3, 10.8 mg kg⁻¹ and 482.1, 165.0, 51.3, 13.1, 10.54 mg kg⁻¹, respectively) compared to all the other treatments during 2013 and 2014. However, lower Fe, Mn, Zn, Cu and B contents were recorded in treatment T₁₃ (405.3, 102.3, 37.3, 10.5, 8.64 mg kg⁻¹ and 365.3, 88.0, 27.3, 9.3, 8.51 mg kg⁻¹, respectively) during 2013 and 2014.

The results of pooled analysis of two years (2013 and 2014) data revealed that the concentrations of Fe, Mn, Zn, Cu and B in tomato fruit varied significantly. Higher concentrations of Fe, Mn, Zn, Cu and B were recorded in the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (510.2, 182.3, 56.3, 13.70 and 10.7 mg kg⁻¹, respectively) compared to all the other treatments. Lower concentrations of Fe, Mn, Zn, Cu and B (385.3, 95.2, 32.3, 9.9 and 8.6 mg kg⁻¹, respectively) were observed in treatment T₁₃ which received 100% RDF + water sprays (5 times)

4.4.7 Nutrient concentration in tomato haulm (leaves and stem) at harvest

The data on concentration of nitrogen, phosphorus and potassium in tomato haulm varied significantly due to foliar application of diluted distillery spentwash at harvest. The concentration of nitrogen, phosphorus and potassium was higher in tomato haulm grown during 2013 compared to 2014.

During both the years (2013 and 2014) nitrogen, phosphorus and potassium concentration in tomato haulm (Table 33) was significantly higher in T₁₂ treatment that received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (1.52, 0.32, 1.71 % and 1.42, 0.31, 1.51 %, respectively) compared with treatment T₁₃ which received 100% RDF + water spray (1.25, 0.16, 1.37 % and 1.15, 0.14, 1.10 % respectively) which recorded lower values.

The pooled analysis of two years data revealed that the concentration of N, P and K in tomato haulm was significantly higher in the treatment T₁₂ that received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (1.47, 0.32 and 1.61 %, respectively). Significantly lower concentration of N, P and K was recorded in the treatment T₁₃ which received 100% RDF+ water spray (1.20, 0.15 and 1.24 %, respectively).

Table 32. Effect of foliar application of diluted distillery spentwash on micronutrients content at harvest of tomato fruit grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(mg kg ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pool
T ₁	411.3	374.2	392.7	107.80	98.00	102.9	38.7	28.7	33.7	11.10	9.90	10.50	8.98	8.84	8.9
T ₂	430.3	385.2	407.7	110.60	101.00	105.8	41.9	31.8	36.8	11.50	10.30	10.90	9.10	9.12	9.1
T ₃	440.3	400.3	420.3	121.40	102.00	111.7	44.2	35.7	39.9	11.30	10.10	10.70	9.20	9.27	9.2
T ₄	453.3	413.3	433.3	127.50	118.00	122.8	46.8	38.3	42.5	11.50	10.30	10.90	9.30	9.40	9.4
T ₅	460.3	420.3	440.3	138.80	120.00	129.4	48.2	39.1	43.6	11.70	10.50	11.10	9.50	9.52	9.5
T ₆	466.3	426.3	446.3	148.50	125.00	136.8	49.2	40.3	44.7	12.20	11.00	11.60	9.60	9.82	9.7
T ₇	469.3	429.3	449.3	159.60	131.00	145.3	50.3	42.8	46.5	12.80	11.60	12.20	9.70	10.08	9.9
T ₈	480.3	440.3	460.3	166.50	140.00	153.3	50.7	43.7	47.2	12.50	11.30	11.90	10.00	10.12	10.1
T ₉	490.3	450.3	470.3	175.30	152.00	163.7	52.8	45.2	49.0	13.10	11.90	12.50	10.20	10.24	10.2
T ₁₀	510.3	470.3	490.3	193.30	160.00	176.7	57.3	48.2	52.7	13.30	12.10	12.70	10.60	10.48	10.5
T ₁₁	501.3	461.3	481.3	183.20	158.00	170.6	55.3	47.3	51.2	13.80	12.60	13.20	10.40	10.38	10.4
T ₁₂	538.3	482.1	510.2	199.50	165.00	182.3	61.3	51.3	56.3	14.30	13.10	13.70	10.80	10.54	10.7
T ₁₃	405.3	365.3	385.3	102.30	88.00	95.2	37.3	27.3	32.3	10.50	9.30	9.90	8.64	8.51	8.6
S. Em±	22.17	18.36	20.04	8.01	8.01	7.84	3.20	4.09	4.71	0.22	0.24	0.32	0.32	0.26	0.19
C. D. at 5%	64.71	53.58	56.92	23.37	23.37	22.28	9.35	11.93	13.37	0.63	0.69	0.92	0.93	0.76	0.56
CV (%)	8.24	7.49	7.80	9.32	10.87	9.83	11.37	15.41	16.21	3.1	3.7	4.7	5.72	4.66	3.45

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 33. Effect of foliar application of diluted distillery spentwash on primary nutrients content in haulm at harvest of tomato crop grown during 2013 and 2014.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	1.28	1.18	1.23	0.18	0.15	0.17	1.42	1.22	1.32
T₂	1.30	1.23	1.27	0.20	0.18	0.19	1.45	1.25	1.35
T₃	1.32	1.22	1.27	0.21	0.19	0.20	1.47	1.27	1.37
T₄	1.34	1.24	1.29	0.23	0.19	0.21	1.50	1.30	1.40
T₅	1.35	1.23	1.29	0.24	0.16	0.20	1.52	1.32	1.42
T₆	1.37	1.27	1.32	0.25	0.18	0.22	1.55	1.35	1.45
T₇	1.38	1.28	1.33	0.27	0.21	0.24	1.57	1.37	1.47
T₈	1.40	1.30	1.35	0.28	0.25	0.27	1.60	1.40	1.50
T₉	1.42	1.32	1.37	0.30	0.25	0.28	1.62	1.42	1.52
T₁₀	1.49	1.39	1.44	0.31	0.28	0.30	1.68	1.42	1.55
T₁₁	1.46	1.36	1.41	0.30	0.26	0.28	1.65	1.45	1.55
T₁₂	1.52	1.42	1.47	0.32	0.31	0.32	1.71	1.51	1.61
T₁₃	1.25	1.15	1.20	0.16	0.14	0.15	1.37	1.10	1.24
S. Em±	0.02	0.02	0.02	0.02	0.02	0.02	0.06	0.05	0.06
C. D. at 5%	0.06	0.06	0.06	0.06	0.05	0.05	0.18	0.14	0.16
CV (%)	2.7	2.9	2.8	15.0	13.1	14.1	7.0	6.3	6.9

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
 T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
 T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
 T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
 T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
 T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
 T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
 T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
 T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
 T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
 T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
 T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
 T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

The concentration of calcium, magnesium and sulphur in tomato haulm varied significantly due to foliar application of diluted distillery spentwash (Table 34).

The concentration of calcium, magnesium and sulphur was higher in tomato crop grown during 2013 as compared to crop grown during 2014. However, significantly higher concentration of calcium, magnesium and sulphur in haulm was observed in treatment T₁₂ treatment that received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (0.46, 0.28, 0.38 % and 0.36, 0.24, 0.31 %, respectively) during both the years. Whereas lower calcium, magnesium and sulphur content was recorded in control (0.26, 0.10, 0.18 % and 0.17, 0.05, 0.11 %, respectively) during 2013 and 2014. While the concentration of Ca, Mg and S in all the other treatments was in between these two treatment values.

Pooled analysis of two years experimental data indicated that Ca, Mg and S concentration in tomato haulm was significantly higher in the treatment T₁₂ that received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (0.41, 0.26 and 0.35 %, respectively). Significantly lower concentration of Ca, Mg and sulphur was recorded in the treatment T₁₃ which received 100% RDF + water spray (0.22, 0.08 and 0.15 %, respectively) and 100% RDF + 4 sprays of undiluted distillery spentwash (0.23, 0.10 and 0.17 %, respectively).

The concentration of micronutrients in tomato haulm as influenced by application of diluted distillery spentwash as foliar spray has been presented in Table 35.

The pooled analysis of two years data revealed that the concentrations of Fe, Zn, Cu, Mn and B in tomato haulm varied significantly. Higher concentration of Fe, Zn, Cu, Mn and B were recorded in the treatment T₁₂ that received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (471.2, 70.2, 13.7 169.3 and 10.5 mg kg⁻¹, respectively) compared to all other treatments and it was on par with treatment T₁₀ which received 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution (464.2, 67.1, 13.4, 161.4 and 10.3 mg kg⁻¹, respectively). However, lower concentrations of Fe, Zn, Cu, Mn and B (292.6, 33.6, 9.9, 89.4 and 8.0 mg kg⁻¹, respectively) observed in control.

4.4.8 Nutrient uptake by whole tomato plant (fruit and haulm) at harvest

The data pertaining to nitrogen, phosphorus and potassium uptake by tomato crop differed significantly due to foliar application of diluted distillery spentwash at harvest (Table 36).

The nitrogen, phosphorus and potassium uptake by tomato crop was higher during 2013 compared to 2014. During both 2013 and 2014 significantly higher nitrogen, phosphorus and potassium uptake by tomato crop was recorded in the treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (216.5, 32.9, 261.4 and 165.3, 25.8, 202.7 kg ha⁻¹, respectively) compared to treatment T₁₃ (133.7, 13.2, 152.4 and 103.3, 9.3, 118.1 kg ha⁻¹, respectively) which received 100% RDF + water spray.

Table 34. Effect of foliar application of diluted distillery spentwash on secondary nutrients content in haulm at harvest of tomato crop grown during 2013 and 2014.

Treatments	Calcium (%)			Magnesium (%)			Sulphur (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	0.28	0.18	0.23	0.13	0.07	0.10	0.20	0.13	0.17
T₂	0.32	0.20	0.26	0.14	0.09	0.12	0.21	0.14	0.18
T₃	0.35	0.22	0.29	0.15	0.10	0.13	0.22	0.15	0.19
T₄	0.36	0.22	0.29	0.16	0.12	0.14	0.23	0.17	0.20
T₅	0.37	0.24	0.31	0.18	0.14	0.16	0.24	0.19	0.22
T₆	0.39	0.25	0.32	0.20	0.15	0.18	0.26	0.20	0.23
T₇	0.40	0.26	0.33	0.21	0.16	0.19	0.29	0.22	0.26
T₈	0.41	0.28	0.35	0.22	0.18	0.20	0.32	0.24	0.28
T₉	0.42	0.31	0.37	0.24	0.20	0.22	0.33	0.26	0.30
T₁₀	0.45	0.35	0.40	0.27	0.22	0.25	0.37	0.29	0.33
T₁₁	0.43	0.32	0.38	0.26	0.21	0.24	0.35	0.28	0.32
T₁₂	0.46	0.36	0.41	0.28	0.24	0.26	0.38	0.31	0.35
T₁₃	0.26	0.17	0.22	0.10	0.05	0.08	0.18	0.11	0.15
S. Em±	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01
C. D. at 5%	0.05	0.06	0.06	0.04	0.03	0.03	0.06	0.04	0.03
CV (%)	8.2	14.5	10.76	11.3	13.1	11.06	12.5	12.8	7.89

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 35. Effect of foliar application of diluted distillery spentwash on micronutrients content in haulm at harvest of tomato crop grown during 2013 and 2014

Treatments	Iron			Manganese			Zinc (mg kg ⁻¹)			Copper			Boron		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	378.2	254.2	316.2	105.6	92.3	99.0	30.2	42.2	36.2	11.5	8.52	10.0	8.7	8.1	8.4
T₂	398.5	265.3	331.9	108.3	98.5	103.4	35.1	45.1	40.1	12.2	9.21	10.7	9.1	8.2	8.7
T₃	403.6	281.2	342.4	115.3	106.5	110.9	38.2	48.2	43.2	12.7	9.25	11.0	9.2	8.5	8.9
T₄	412.3	290.3	351.3	120.3	112.3	116.3	45.8	50.8	48.3	13.0	9.53	11.3	9.2	8.8	9.0
T₅	424.2	318.2	371.2	126.5	116.2	121.4	51.2	51.2	51.2	13.1	9.84	11.5	9.3	9.1	9.2
T₆	438.6	332.1	385.4	134.0	120.5	127.3	55.6	55.6	55.6	13.3	10.1	11.7	9.6	9.2	9.4
T₇	442.2	351.2	396.7	146.2	128.1	137.2	57.3	57.3	57.3	13.6	10.7	12.2	9.7	9.5	9.6
T₈	454.2	370.2	412.2	153.2	134.2	143.7	60.1	60.1	60.1	13.7	11.2	12.4	9.8	9.8	9.8
T₉	468.6	382.6	425.6	160.1	140.1	150.1	63.7	60.7	62.2	13.8	11.8	12.8	10.1	9.9	10.0
T₁₀	508.3	420.1	464.2	172.6	150.2	161.4	72.1	62.1	67.1	14.1	12.7	13.4	10.4	10.3	10.3
T₁₁	497.2	402.6	449.9	169.3	148.2	158.8	69.8	59.8	64.8	14.0	12.5	13.3	10.2	10.1	10.2
T₁₂	512.2	430.2	471.2	180.2	158.3	169.3	75.2	65.2	70.2	14.2	13.2	13.7	10.6	10.4	10.5
T₁₃	318.2	267.0	292.6	98.2	80.6	89.4	27.6	39.6	33.6	11.3	8.4	9.9	8.4	7.7	8.0
S. Em±	17.68	32.03	25.35	8.01	8.01	7.84	2.17	2.18	2.28	0.32	0.22	0.27	0.35	0.38	0.33
C. D. at 5%	51.60	93.48	71.99	23.37	23.37	22.28	6.33	6.35	6.49	0.93	0.63	0.77	1.01	1.12	0.96
CV (%)	7.0	16.5	11.39	10.1	11.4	10.46	7.2	7.0	7.5	4.2	3.6	4.0	6.3	7.2	6.08

Legend:

- | | |
|------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| T ₁ : 100% RDF + 4 sprays of undiluted distillery spentwash | T ₈ : 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution |
| T ₂ : 100% RDF + 5 sprays of undiluted distillery spentwash | T ₉ : 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution |
| T ₃ : 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution | T ₁₀ : 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution |
| T ₄ : 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution | T ₁₁ : 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution |
| T ₅ : 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution | T ₁₂ : 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution |
| T ₆ : 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution | T ₁₃ : 100% RDF + water sprays (5 times) |
| T ₇ : 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution | |

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 36. Effect of foliar application of diluted distillery spentwash on primary nutrients uptake at harvest by tomato crop grown during 2013 and 2014.

Treatments	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	139.1	107.4	123.2	14.3	10.1	12.2	159.3	124.6	141.9
T₂	146.2	113.9	130.1	17.1	12.7	14.9	170.3	133.9	152.1
T₃	157.1	119.7	138.4	18.9	14.2	16.5	184.4	142.3	163.3
T₄	164.4	121.7	143.1	20.9	14.7	17.8	194.6	146.2	170.4
T₅	175.5	128.6	152.0	22.8	15.0	18.9	208.3	155.7	182.0
T₆	180.7	128.6	154.7	24.4	16.1	20.3	219.6	159.2	189.4
T₇	179.8	135.2	157.5	25.3	18.0	21.7	219.4	168.5	193.9
T₈	192.0	140.7	166.4	28.2	20.5	24.3	231.7	172.8	202.3
T₉	195.1	143.9	169.5	28.2	20.1	24.1	239.3	179.9	209.6
T₁₀	210.2	159.3	184.7	31.4	23.7	27.6	254.7	194.9	224.8
T₁₁	207.8	159.1	183.4	31.5	23.8	27.6	249.1	193.9	221.5
T₁₂	216.5	165.3	190.9	32.9	25.8	29.4	261.4	202.7	232.1
T₁₃	133.7	103.3	118.5	13.2	9.3	11.2	152.4	118.1	135.3
S. Em±	8.00	4.44	6.34	1.03	0.50	0.79	9.52	5.52	7.64
C. D. at 5%	23.34	12.95	18.02	3.00	1.46	2.26	27.78	16.11	21.70
CV (%)	7.8	5.8	7.1	7.5	5.0	6.7	7.8	5.9	7.1

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

The pooled analysis of data of two years (2013 and 2014) indicated that significantly higher nitrogen, phosphorus and potassium uptake by tomato crop was noticed in the treatment T₁₂ (190.9, 29.4 and 232.1 kg ha⁻¹, respectively) receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution. However, significantly lower nitrogen, phosphorus and potassium uptake by tomato crop was noticed in treatment T₁₃ receiving 100% RDF + water sprays (118.5, 11.2 and 135.3 kg ha⁻¹, respectively).

The uptake of calcium, magnesium and sulphur by tomato crop differed significantly due to foliar spray of distillery spentwash (Table 37) at different dilution.

During 2013, the uptake of Ca, Mg and S was lower in treatment T₁₃ which received 100% RDF + water spray (18.3, 8.8 and 15.6 kg ha⁻¹ respectively) and uptake of 49.7, 30.8, 42.0 kg ha⁻¹ respectively was significantly higher due to 5 sprays of distillery spentwash at 1:5 dilution (T₁₂). Similar trend was observed in 2014.

The results of pooled analysis of two years data revealed that 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) recorded significantly higher uptake of Ca, Mg and S (42.3, 27.0 and 36.5 kg ha⁻¹, respectively) by tomato crop compared to all the other treatments. However, significantly lower uptake of Ca, Mg and S by tomato crop (15.6, 6.7 and 12.3 kg ha⁻¹, respectively) was observed in the treatment T₁₃ which received 100% RDF + water sprays.

The results on uptake of Fe, Mn, Zn, Cu and B by tomato crop varied significantly due to foliar application of diluted distillery spentwash at harvest (Table 38). The uptake of micronutrients by tomato crop was higher in 2013 compared to 2014.

During 2013, higher uptake of Fe, Mn, Zn, Cu and B were recorded with 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (T₁₂) (5563, 2027, 694.0, 149.9 and 112.8 g ha⁻¹) compared to all the other treatments. Similar trend was observed during 2014.

Pooled analysis showed significantly higher uptake of Fe, Mn, Zn, Cu and B by tomato crop in the treatment T₁₂ that received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (4917, 1762, 605.1, 135.4 and 104.7 g ha⁻¹, respectively). Lower uptake of Fe, Mn, Zn, Cu and B by tomato crop (2460, 649, 225.7, 68.9 and 58.2 g ha⁻¹, respectively) was observed in the treatment T₁₃ which received 100% RDF + water sprays.

Significantly higher concentration of cations (Ca, Mg and K) and anions (N, P and S) in tomato fruit, haulm and nutrient uptake by the tomato crop at harvest during 2013 and 2014 was observed with the foliar application of diluted distillery spentwash (Table 30 to 38). Significantly higher concentration and uptake of all the nutrients was recorded in treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution and it was on par with T₁₀ which received 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution.

Table 37. Effect of foliar application of diluted distillery spentwash on secondary nutrients uptake at harvest by tomato crop grown during 2013 and 2014.

Treatments	Calcium (kg ha ⁻¹)			Magnesium (kg ha ⁻¹)			Sulphur (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	22.3	13.7	18.0	11.1	6.0	8.5	17.3	10.4	13.8
T₂	26.4	15.8	21.1	12.4	7.7	10.0	18.9	11.6	15.2
T₃	30.3	18.0	24.2	14.0	8.8	11.4	20.8	12.9	16.9
T₄	32.7	18.2	25.4	15.5	10.3	12.9	22.6	14.5	18.5
T₅	35.1	20.4	27.7	18.0	12.2	15.1	24.6	16.6	20.6
T₆	38.0	21.2	29.6	20.4	13.1	16.7	27.3	17.4	22.3
T₇	38.4	22.8	30.6	21.0	14.3	17.7	29.6	19.6	24.6
T₈	41.3	24.8	33.1	23.0	16.2	19.6	32.6	21.6	27.1
T₉	43.2	28.1	35.6	25.5	17.8	21.7	34.4	23.9	29.1
T₁₀	48.0	32.7	40.4	29.3	21.0	25.2	38.3	28.5	33.4
T₁₁	46.2	31.3	38.7	28.0	20.2	24.1	37.9	27.7	32.8
T₁₂	49.7	34.9	42.3	30.8	23.3	27.0	42.0	30.9	36.5
T₁₃	18.3	12.8	15.6	8.8	4.6	6.7	15.6	8.9	12.3
S. Em±	1.57	0.69	1.19	0.82	0.41	0.64	1.17	0.58	0.91
C. D. at 5%	4.58	2.01	3.39	2.39	1.19	1.81	3.40	1.69	2.57
CV (%)	7.53	5.26	7.02	7.15	5.22	6.61	7.26	5.33	6.72

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution

T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table 38. Effect of foliar application of diluted distillery spentwash on micronutrients uptake at harvest by tomato crop grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(g ha ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	2970	2219	2595	795	636	716	265.8	218.7	242.2	83.4	62.5	73.0	66.0	56.9	61.4
T ₂	3253	2408	2831	851	696	774	306.7	250.8	278.8	91.0	69.1	80.0	70.5	61.4	66.0
T ₃	3510	2630	3070	978	759	869	354.6	293.7	324.2	96.2	71.7	84.0	75.4	66.0	70.7
T ₄	3777	2736	3257	1075	856	966	408.0	314.2	361.1	103.4	73.9	88.7	79.7	67.8	73.7
T ₅	4028	2954	3491	1211	907	1059	457.0	337.3	397.2	109.3	78.5	93.9	84.8	71.7	78.2
T ₆	4238	3033	3636	1333	947	1140	481.6	347.6	414.6	116.1	82.1	99.1	89.0	73.9	81.4
T ₇	4205	3207	3706	1419	1032	1226	495.8	376.7	436.3	119.3	89.8	104.6	88.6	78.6	83.6
T ₈	4525	3377	3951	1555	1119	1337	528.1	386.4	457.2	123.6	91.3	107.4	95.3	81.1	88.2
T ₉	4743	3567	4155	1671	1236	1453	558.8	417.8	488.3	131.0	99.1	115.1	99.7	84.6	92.1
T ₁₀	5278	4085	4682	1931	1411	1671	587.4	419.5	503.5	144.0	113.7	128.9	109.0	93.8	101.4
T ₁₁	5128	3985	4557	1831	1396	1614	617.0	452.6	534.8	138.8	110.4	124.6	106.0	92.8	99.4
T ₁₂	5563	4270	4917	2027	1497	1762	694.0	516.2	605.1	149.9	120.8	135.4	112.8	96.5	104.7
T ₁₃	2749	2171	2460	741	557	649	248.5	202.9	225.7	79.3	58.6	68.9	62.9	53.5	58.2
S. Em±	180.98	98.75	143.17	55.28	30.49	43.88	20.29	10.00	15.69	5.00	2.69	3.94	3.85	2.35	3.13
C. D. at 5%	528.23	288.23	406.67	161.35	89.00	124.64	59.21	29.18	44.56	14.60	7.84	11.20	11.23	6.86	8.89
CV (%)	7.55	5.47	6.81	7.15	5.26	6.49	7.6	5.0	6.7	7.6	5.39	6.81	7.60	5.41	6.65

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution

T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

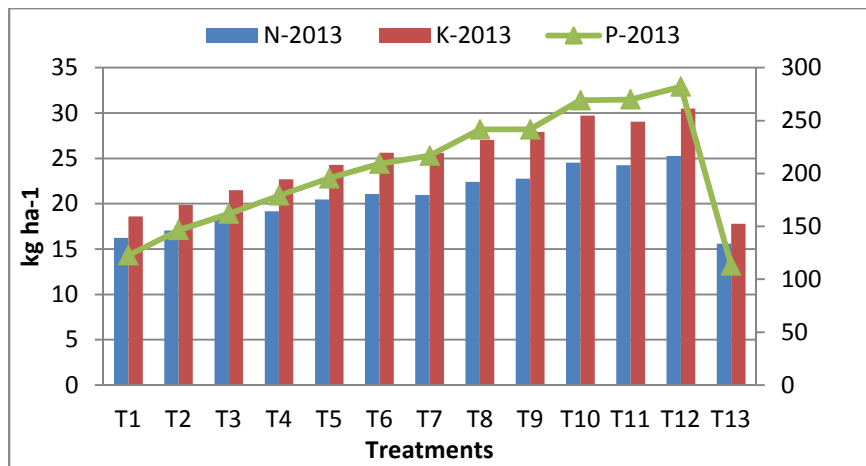


Fig. 7: Primary nutrient uptake by tomato crop grown during 2013 as influenced by foliar application of diluted distillery spentwash

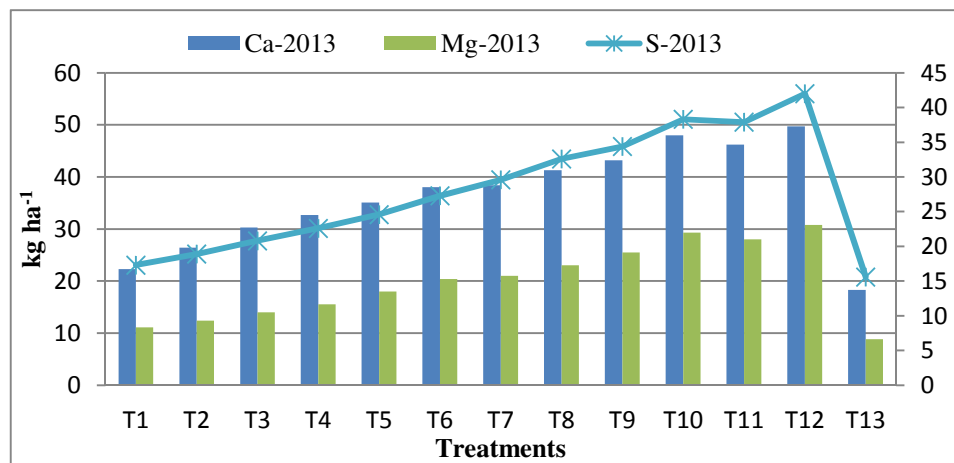


Fig. 8: Secondary nutrient uptake by tomato crop grown during 2013 as influenced by foliar application of diluted distillery spentwash

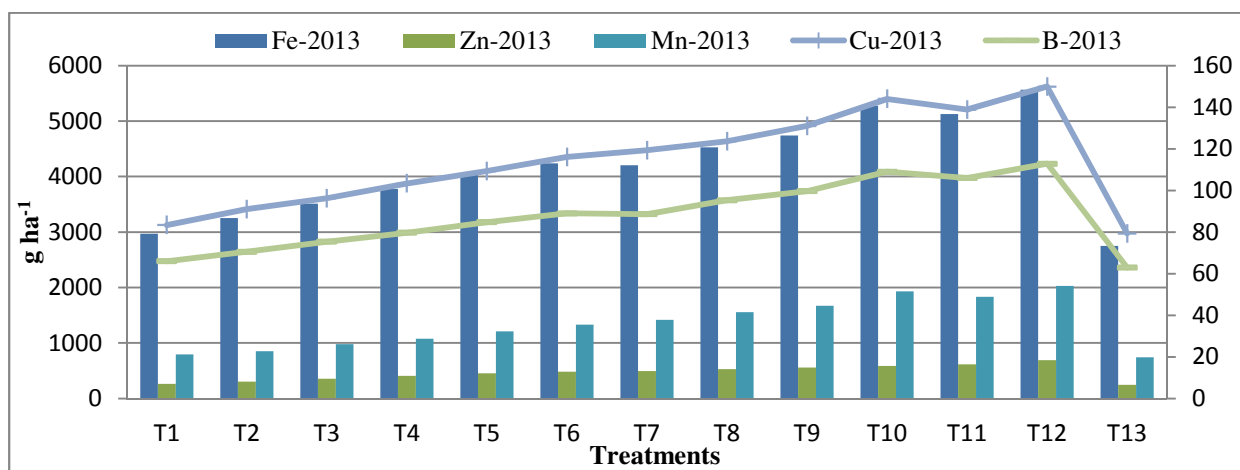


Fig. 9: Micronutrient uptake by tomato crop grown during 2013 as influenced by foliar application of diluted distillery spentwash

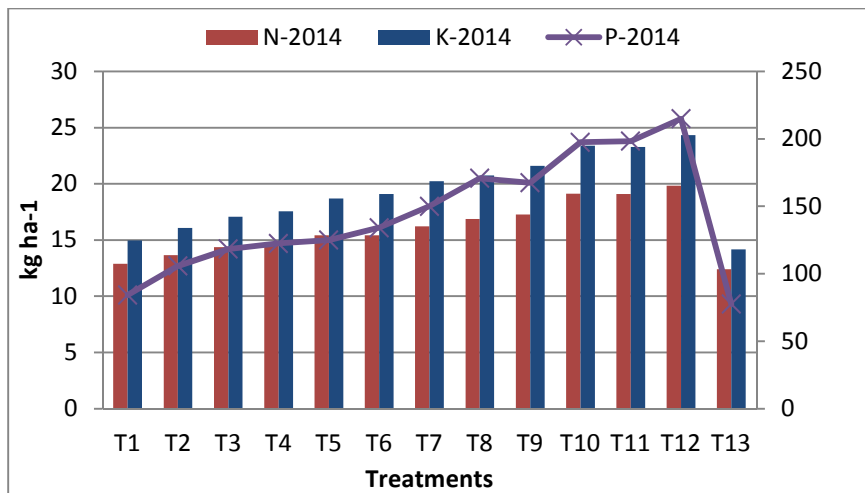


Fig. 10: Primary nutrient uptake by tomato crop grown during 2014 as influenced by foliar application of diluted distillery spentwash

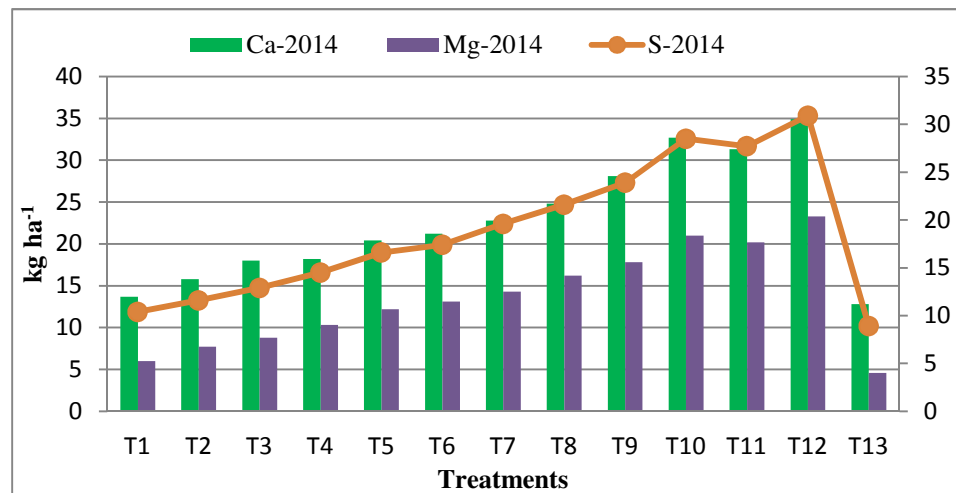


Fig. 11: Secondary nutrient uptake by tomato crop grown during 2014 as influenced by foliar application of diluted distillery spentwash

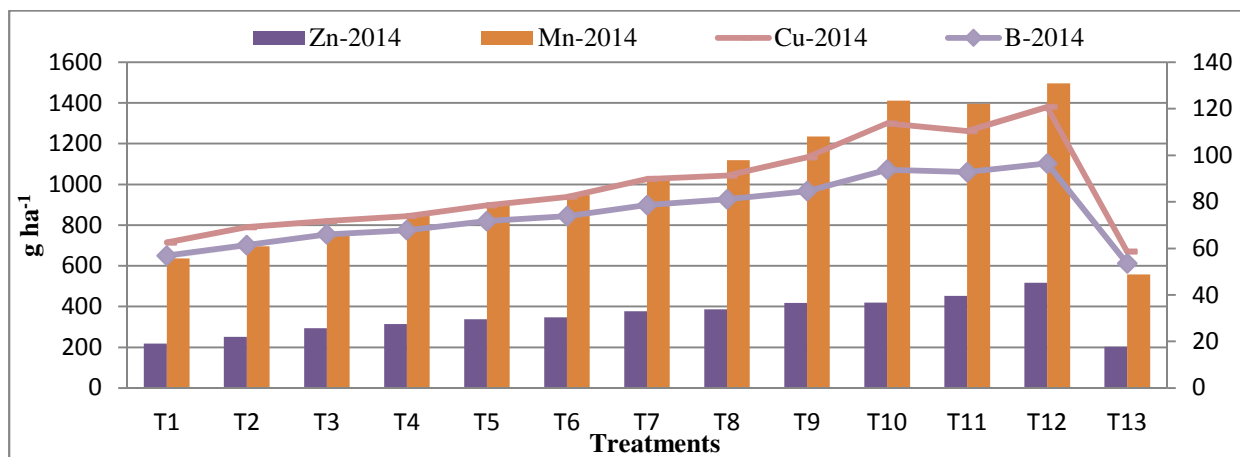


Fig. 12: Micronutrient uptake by tomato crop grown during 2014 as influenced by foliar application of diluted distillery spentwash

This is because of protein, fiber, carbohydrate, energy, nitrogen, potassium, magnesium and phosphorous were much more in the case of 1:5 dilution of spentwash than water. This could be due to the more absorption of plant nutrients present in spentwash by plants at higher dilutions. Chandraju *et al.* (2012) reported that application of distillery spentwash did not have negative impact of heavy metals like lead, cadmium and nickel on the leaves of V-1 mulberry plants. Kulkarni *et al.* (1987) classified spentwash as dilute liquid organic fertilizer with high K content. They observed that N was mostly in colloid form behaving as a slow release fertilizer better than most inorganic N sources. Significantly higher concentration and uptake of all the nutrients was recorded in treatment T₁₃ which received 100% RDF +water spray this could be due to lesser availability of plant nutrients.

Similarly higher concentration and uptake of micronutrients was found in treatment with foliar application of 1:5 diluted distillery spentwash compared to all the other treatments. Higher nutrient concentration and uptake was observed in treatment receiving foliar application of diluted distillery spentwash since plants absorb 30-40% of spray solution at the time of foliar application and remaining spray solution drops fall on soil surface which improves soil physical and chemical conditions that might have increased the availability of nutrients. The increase in uptake of nutrients may also be due to mineralization of organic material as well as nutrients present in the spentwash and hence responsible for increased availability of plant nutrients (Ramana *et al* 2001) and also diluted spentwash application improved the physical and chemical properties of the soil and further increased the soil micro flora. Diluted spentwash increased the uptake of nutrients, growth and yield of leafy vegetables (Chandraju, *et al.* 2011) and nutrients content of top vegetable (Manivasakam, 1987).

4.4.9 Changes in soil properties after harvest of tomato crop

Chemical properties

The changes in pH, electrical conductivity and organic carbon content of soil after the harvest of tomato crop due to foliar application of diluted distillery spentwash are presented in Table 39. The available nutrient status of soil after harvest of tomato crop was higher in 2014 compared to 2013. At the time of foliar application of diluted distillery spentwash plants absorb only 30-40% of spray solution and the remaining solution drops fall on soil surface and the soil properties measured were higher during 2014 compared to 2013, due to cumulative effect.

The pH, electrical conductivity and organic carbon content of soil were in general higher after the harvest of tomato crop compared to initial value.

Table 39. Effect of foliar application of diluted distillery spentwash on pH, electrical conductivity and organic carbon content of soil after the harvest of tomato crop grown during 2013 and 2014.

Treatments	pH (1:2.5)			EC (dSm ⁻¹)			Organic carbon (g kg ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	7.64	7.74	7.69	0.32	0.46	0.39	7.20	7.70	7.50
T₂	7.65	7.80	7.73	0.33	0.49	0.41	7.40	7.80	7.60
T₃	7.64	7.72	7.68	0.31	0.41	0.36	6.70	7.40	7.10
T₄	7.67	7.75	7.71	0.30	0.43	0.36	7.10	7.60	7.30
T₅	7.65	7.71	7.68	0.31	0.39	0.35	6.30	7.70	7.00
T₆	7.63	7.73	7.68	0.31	0.40	0.36	6.50	7.10	6.80
T₇	7.62	7.68	7.65	0.32	0.35	0.34	6.00	6.50	6.30
T₈	7.60	7.70	7.65	0.30	0.37	0.34	5.90	6.80	6.30
T₉	7.63	7.66	7.65	0.31	0.32	0.31	5.40	6.20	5.80
T₁₀	7.61	7.67	7.64	0.29	0.34	0.32	5.60	6.40	6.00
T₁₁	7.65	7.69	7.67	0.28	0.28	0.28	5.20	6.00	5.60
T₁₂	7.64	7.68	7.66	0.27	0.30	0.29	5.30	6.20	5.80
T₁₃	7.79	7.83	7.81	0.14	0.20	0.17	4.90	5.40	5.20
S. Em±	0.06	0.06	0.06	0.02	0.03	0.01	0.05	0.05	0.01
C. D. at 5%	NS	NS	NS	0.06	0.08	0.02	0.16	0.15	0.04
CV (%)	1.3	1.2	1.3	12.60	12.96	12.92	15.10	12.85	13.77
Initial value	7.55			0.15			4.20		

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

There was no significant difference in the soil pH during 2013 and 2014 due to foliar application of diluted distillery spentwash. Soil pH was slightly increased after the harvest of tomato crop compared to initial pH values (7.55). The results are in accordance with Singh and Raj Bahadur (1998) who observed marginal increase in pH of soil with application of distillery spentwash. This may be attributed to the addition of soluble salts through foliar application of distillery spentwash. However, electrical conductivity and organic carbon content of soil was significantly higher in treatment T₂ which received 100% RDF + 5 sprays of undiluted distillery spentwash (0.33, 0.49 dSm⁻¹ and 7.40, 7.80 g kg⁻¹ during 2013 and 2014, respectively) compared to all the other treatments. The EC of the post harvest soil increased appreciably compared to the initial value due to the application of undiluted treated distillery spentwash (T₂). The spentwash contains high amount of soluble salt which may accumulate on surface of the soil. The EC of the treated distillery spentwash applied soil plots was well within the safer limit. The findings of study by Selvakumar (2006) also support the results of the present study. The increase in organic content of soil might be due to decomposition and humification of organic matter in soil supplied through distillery spentwash. Lower electrical conductivity and organic carbon content of soil was recorded in treatment T₁₃ which received only water spray (0.14, 0.20 dSm⁻¹ and 4.90, 5.40 g kg⁻¹) during 2013 and 2014, respectively. This is because of very low and absence of organic matter in the water used for foliar spray.

The pooled analysis of two years data showed significantly higher salt content and organic carbon content in soil was recorded in treatment T₂ which received 100% RDF + 5 sprays of undiluted distillery spentwash (0.41 dSm⁻¹ and 7.60 g kg⁻¹ during 2013 and 2014, respectively) compared to all the other treatments. However, significantly lower salt content and organic carbon content (0.17 dSm⁻¹ and 5.20 g kg⁻¹) of soil was recorded in treatment T₁₃ which received only water spray.

Data pertaining to changes in the available nitrogen, phosphorus and potassium content of soil at the harvest of tomato crop due to foliar application of diluted distillery spentwash are presented in Table 40.

The available nitrogen, phosphorus and potassium content of soil were higher in most of the treatments during 2014 compared to 2013.

After the harvest of crop in 2013, the significantly higher available nitrogen, phosphorus and potassium content (268.4, 34.6 and 383.0 kg ha⁻¹, respectively) of soil was recorded in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash. Satisha (2000) reported that addition of organic matter in the form of treated distillery spentwash would provide N for the multiplication of microbes and subsequent increase in the nutrient availability during the decomposition in sugarcane. The higher phosphorus might be due to the decomposition processes of easily degradable organics which might have reduced the binding energy and P sorption capacity of the soil thus favouring higher P availability in the soil. Similar results were reported by Murugaragavan (2002). However, higher potassium in soil which might be due to the fact that K was one of the components supplied in larger quantities as reported by Dinesh (2011).

Table 40. Effect of foliar application of diluted distillery spentwash on available nitrogen, phosphorus and potassium content of soil after the harvest of tomato crop grown during 2013 and 2014.

Treatments	Available-N (kg ha ⁻¹)			Available-P ₂ O ₅ (kg ha ⁻¹)			Available-K ₂ O (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	265.4	270.9	268.1	33.7	35.7	34.7	382.3	387.0	384.6
T₂	268.4	274.1	271.3	34.6	36.9	35.7	383.0	396.5	389.8
T₃	236.2	254.5	245.4	30.4	32.4	31.4	379.5	384.3	381.9
T₄	241.0	256.7	248.8	30.9	33.9	32.4	381.4	386.9	384.2
T₅	223.2	229.9	226.6	28.4	30.4	29.4	381.2	379.5	380.3
T₆	224.1	230.0	227.1	29.6	32.5	31.0	370.1	382.6	376.3
T₇	219.7	226.5	223.1	27.8	29.8	28.8	371.4	368.9	370.2
T₈	226.9	226.9	226.9	28.3	31.3	29.8	363.7	372.1	367.9
T₉	206.1	211.4	208.8	26.5	28.5	27.5	360.0	356.2	358.1
T₁₀	215.5	221.3	218.4	27.1	30.0	28.6	351.4	362.0	356.7
T₁₁	192.5	198.3	195.4	25.4	27.4	26.4	334.5	340.2	337.3
T₁₂	195.2	202.1	198.7	26.3	29.2	27.8	338.5	343.6	341.1
T₁₃	227.0	232.4	229.7	28.1	29.8	29.0	356.6	362.2	359.4
S. Em±	15.3	15.5	15.16	1.7	1.7	1.7	11.1	11.6	11.38
C. D. at 5%	44.6	45.2	43.05	5.0	5.1	4.82	32.4	33.9	32.32
CV (%)	11.7	11.5	11.2	10.3	9.6	9.7	5.3	5.4	5.3
Initial value	223.2 (kg ha⁻¹)			30.5 (kg ha⁻¹)			360.5 (kg ha⁻¹)		

Legend:

- T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution
T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Significantly lower available nitrogen, phosphorus and potassium content (192.5, 25.4 and 334.5 kg ha⁻¹, respectively) of soil was observed in treatment T₁₁ receiving 100% RDF + 4 sprays of distillery spentwash at 1:5 dilutions during 2013. This might be due to greater uptake by tomato crop and also translocation of nutrients to various plant parts like stem, fruits and leaves. Similar trend was observed after the harvest of the crop during 2014.

Pooled analysis of two years data also showed significantly higher available nitrogen, phosphorus and potassium content (271.3, 35.7 and 389.8 kg ha⁻¹, respectively) of soil in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash compared to all the other treatments. However, significantly lower available nitrogen, phosphorus and potassium content (195.4, 26.4 and 337.3 kg ha⁻¹, respectively) of soil was observed in treatment T₁₁ receiving 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution was during 2013 and 2014.

Data on the effect of foliar application of distillery spentwash of different dilutions on exchangeable-calcium, magnesium, sodium and available sulphur content of soil after the harvest of tomato crop are presented in Table 41.

The exchangeable-calcium, magnesium, sodium and available sulphur contents of soil were higher in most of the treatments during 2014 compared to 2013. Significantly higher exchangeable calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash (7.62, 3.57, 0.98 c mol (p+) kg⁻¹ and 22.5 mg kg⁻¹, respectively) compared to all the other treatments during 2013. During distillation of molasses, lime is added in distilleries to increase the pH towards neutrality, which ultimately accumulates in spentwash and is added to soil upon its application either through soil or foliar application. Increased Ca+Mg content in the soil was due to the presence of 1452 mg L⁻¹ of Ca and 790 mg L⁻¹ of Mg in treated spentwash that was applied through foliar spray in different quantities which helped in better replacement of exchangeable sodium by Ca ions. The higher sodium content was observed in the treatment receiving foliar spray of undiluted spentwash. This may be attributed to higher content of sodium containing soluble salts in the distillery spentwash. Since the crop removal of sodium might be lower compared to the amount added, there was a build up in the soil with the advancement of crop growth. These results are in line with the findings of Bhagyalakshmi (2009) and Senthilraja (2010). Similar trend of results were observed in 2014. However, lower calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T₁₁ receiving 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution (6.43, 2.34, 0.56 c mol (p+) kg⁻¹ and 13.5 mg kg⁻¹, respectively) during 2013. This is because of higher uptake of these ions by the crop.

Table 41. Effect of foliar application of diluted distillery spentwash on exchangeable calcium, magnesium, sodium and available sulphur content of soil after the harvest of tomato crop grown during 2013 and 2014.

Treatments	Exch. Ca (c mol (p+) kg ⁻¹)			Exch. Mg (c mol (p+) kg ⁻¹)			Exch. Na (c mol (p+) kg ⁻¹)			Avail-S (mg kg ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	7.55	8.12	7.84	3.48	3.72	3.60	0.94	1.10	1.02	22.2	25.0	23.6
T ₂	7.62	8.21	7.91	3.57	3.81	3.69	0.98	1.12	1.05	22.5	25.7	24.1
T ₃	7.46	7.86	7.66	3.42	3.54	3.48	0.82	1.03	0.93	21.0	24.4	22.7
T ₄	7.49	7.95	7.72	3.52	3.62	3.57	0.85	1.06	0.96	21.1	25.3	23.2
T ₅	7.20	7.58	7.39	3.21	3.36	3.29	0.76	0.95	0.86	18.9	24.2	21.6
T ₆	7.28	7.72	7.50	3.31	3.51	3.41	0.78	0.99	0.89	19.2	24.7	22.0
T ₇	6.98	7.25	7.11	2.98	3.21	3.10	0.67	0.88	0.78	18.5	22.8	20.7
T ₈	7.01	7.35	7.18	3.01	3.34	3.18	0.70	0.92	0.81	18.6	23.8	21.2
T ₉	6.63	6.98	6.81	2.64	3.08	2.86	0.61	0.82	0.72	15.5	20.0	17.8
T ₁₀	6.77	7.12	6.94	2.75	3.13	2.94	0.64	0.85	0.75	15.9	20.9	18.4
T ₁₁	6.43	6.66	6.54	2.34	2.84	2.59	0.56	0.76	0.66	13.5	17.8	15.7
T ₁₂	6.52	6.71	6.62	2.53	2.91	2.72	0.59	0.80	0.70	13.7	18.3	16.0
T ₁₃	7.27	7.44	7.35	3.50	3.39	3.45	0.51	0.65	0.58	16.8	22.2	19.5
S. Em±	0.06	0.06	0.06	0.09	0.06	0.08	0.06	0.06	0.05	1.6	1.2	1.4
C. D. at 5%	0.16	0.17	0.16	0.27	0.18	0.23	0.17	0.17	0.16	4.7	3.6	4.15
CV (%)	1.4	1.3	1.3	5.1	3.1	4.1	14.34	10.81	12.12	15.4	9.4	12.2
Initial value	7.5 (c mol (p+) kg⁻¹)			3.2 (c mol (p+) kg⁻¹)			0.44 (c mol (p+) kg⁻¹)			18.6 (mg kg⁻¹)		

Legend:

- | | |
|------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
| T ₁ : 100% RDF + 4 sprays of undiluted distillery spentwash | T ₈ : 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution |
| T ₂ : 100% RDF + 5 sprays of undiluted distillery spentwash | T ₉ : 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution |
| T ₃ : 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution | T ₁₀ : 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution |
| T ₄ : 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution | T ₁₁ : 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution |
| T ₅ : 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution | T ₁₂ : 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution |
| T ₆ : 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution | T ₁₃ : 100% RDF + water sprays (5 times) |
| T ₇ : 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution | |

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

The pooled analysis data of two years (2013 and 2014) revealed significantly higher exchangeable calcium, magnesium, sodium and available sulphur content of soil in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash (7.91, 3.69, 1.05 c mol (p+) kg⁻¹ and 24.1 mg kg⁻¹, respectively) compared to all the other treatments during 2013. The treatment T₁ receiving 100% RDF + 5 sprays of undiluted distillery spentwash (7.84, 3.60, 1.02 c mol (p+) kg⁻¹ and 23.6 mg kg⁻¹) was found to be on par with each other. However, significantly lower calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T₁₁ receiving 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution (6.54, 2.59, 0.66 c mol (p+) kg⁻¹ and 15.7 mg kg⁻¹, respectively)

Data pertaining to the effect of foliar application of diluted distillery spentwash on DTPA extractable micronutrients and available boron content of soil after the harvest of tomato crop are presented in Table 42.

There was no significant variation in the DTPA extractable iron, manganese, zinc, copper and available boron contents of soil after the harvest of tomato during both the years but the values were higher in most of the treatments during 2014 compared to 2013. Higher DTPA extractable iron, manganese, zinc, copper and available boron contents of soil were observed in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash (9.3, 5.78, 1.50, 0.71 and 0.22 mg kg⁻¹ soil respectively) compared to all the other treatments during 2013. Devarajan *et al.* (1996) reported that the zinc, iron, copper and manganese content of the soil were increased due to fertigation with ten times diluted distillery effluent. Baskar *et al.* (2003). Reported that increased availability might be due to direct contribution from the effluent as well as solubilization and chelation effect of organic matter supplied by the effluent. Similar trend of results were observed in 2014. Lower DTPA extractable iron, manganese, zinc, copper and available boron contents of soil were observed in treatment T₁₁ receiving 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution (7.0, 4.74, 1.34, 0.59 and 0.15 mg kg⁻¹, respectively) during 2013. This might be due to higher uptake of micronutrients by the crop and because of addition of organic manures, synergistic interaction between sulphur and available micronutrients in soil. The application of organic manure along with NPK and S might have improved the micronutrients content in soil.

Pooled analysis of data of two years (2013 and 2014) revealed that higher DTPA extractable iron, manganese, zinc, copper and available boron contents of soil (Table 42) were observed in the treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash (11.7, 6.12, 1.89, 0.81 and 0.25 mg kg⁻¹, respectively) compared to all the other treatments. However, lower DTPA extractable iron, manganese, zinc, copper and available boron contents of soil were observed in treatment T₁₁ receiving 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution (8.78, 4.19, 1.62, 0.68 and 0.18 mg kg⁻¹, respectively) during 2013. Similar trend of results were observed in 2014.

Table 42. Effect of foliar application of diluted distillery spentwash on available iron, manganese, zinc, copper and boron content of soil after the harvest of tomato crop grown during 2013 and 2014.

Treatments	DTPA-Fe			DTPA-Mn			DTPA-Zn			DTPA-Cu			Hot water-B		
	(mg kg ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	9.1	13.9	11.5	5.64	6.28	5.96	1.46	2.23	1.85	0.70	0.88	0.79	0.21	0.28	0.25
T ₂	9.3	14.2	11.7	5.78	6.45	6.12	1.50	2.28	1.89	0.71	0.90	0.81	0.22	0.27	0.25
T ₃	8.5	13.1	10.7	5.45	6.15	5.80	1.40	2.18	1.79	0.68	0.85	0.76	0.20	0.27	0.24
T ₄	8.6	13.5	11.0	5.53	6.24	5.89	1.44	2.21	1.83	0.69	0.87	0.78	0.21	0.28	0.25
T ₅	8.3	12.4	10.3	5.18	6.05	5.62	1.39	2.09	1.74	0.65	0.84	0.75	0.19	0.26	0.23
T ₆	8.8	12.8	10.8	5.20	6.10	5.65	1.41	2.12	1.77	0.66	0.85	0.76	0.17	0.27	0.22
T ₇	8.0	11.7	9.83	5.06	5.92	5.49	1.37	2.05	1.71	0.62	0.81	0.72	0.16	0.24	0.20
T ₈	8.2	12.1	10.1	5.12	6.01	5.57	1.38	2.07	1.73	0.63	0.83	0.73	0.19	0.26	0.23
T ₉	7.4	11.1	9.28	4.94	5.78	5.36	1.37	1.97	1.67	0.62	0.76	0.69	0.19	0.21	0.20
T ₁₀	7.3	11.4	9.37	5.01	5.84	5.43	1.36	2.01	1.69	0.60	0.80	0.70	0.17	0.24	0.21
T ₁₁	7.0	10.6	8.78	4.74	5.05	4.91	1.34	1.89	1.62	0.59	0.77	0.68	0.15	0.20	0.18
T ₁₂	7.3	11.1	9.17	4.82	5.71	5.27	1.35	1.91	1.63	0.60	0.79	0.69	0.17	0.22	0.19
T ₁₃	7.8	12.4	10.1	4.78	5.64	5.19	1.40	1.95	1.68	0.59	0.78	0.69	0.18	0.21	0.19
S. Em±	0.8	1.0	0.9	0.9	0.4	0.1	0.03	0.2	0.04	0.1	0.1	0.02	0.02	0.03	0.01
C. D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	16.5	14.2	16.0	5.45	11.98	10.65	4.6	18.3	15.5	15.7	16.1	15.8	19.4	18.5	19.3
Initial value	7.64 (mg kg⁻¹)			4.98 (mg kg⁻¹)			1.04 (mg kg⁻¹)			0.64 (mg kg⁻¹)			0.28 (mg kg⁻¹)		

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution

T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

4.5 Field Experiment-II: To determine the optimum proportion of nutrients for preparation of fortified spentwash and to study the effect of fortified spentwash on growth and yield of tomato and soil properties

In the farmer's field experiments conducted at Gurudevahalli, Maddur taluk, Mandya District during 2013 and 2014, the growth, yield and quality parameters and nutrients uptake by tomato crop were lower in most of the treatments during 2014 compared to 2013. This could be due to heavy rain during 2014 which resulted in water stagnation in the experimental field. Since tomato crop is highly sensitive to water stagnation, it resulted in decreased growth, yield and quality parameters during 2014 compared to 2013. The results obtained from the field experiments are briefly discussed in the following sections.

4.5.1 Plant growth parameters

The data on plant height, number of branches plant⁻¹ and chlorophyll content of tomato during 2013 and 2014 as influenced by fortified SW 1 (fortified with nitrogen) and SW 2 (fortified with nitrogen, zinc and boron) at different growth stages are presented in Tables 43, 44 & 45 & Plate 5.

Plant height

The data on plant height at different growth stages as influenced by foliar application of fortified spentwash are presented in Table 43. However, the growth parameters were lower in most of the treatments during 2014 compared to 2013

At 30 DAT, plant height and SPAD chlorophyll meter reading did not differ significantly due to foliar application of fortified distillery spentwash during 2013 and 2014.

At 60 DAT, plant height showed significant difference with respect to foliar application of fortified distillery spentwash during 2013 and 2014. Significantly higher plant height was observed during 2013 and 2014 in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (124.5 cm and 112.8 cm, respectively). This could be due to distillery spentwash contains some amounts of NPK and also contain appreciable amount of secondary and micronutrients, besides it was fortified with nitrogen, zinc and boron. Foliar application of these nutrients resulted in better crop growth and thus increased the crop yield. The foliar spray of micronutrients has been reported to be equally or even more effective as soil application to overcome micronutrients deficiency in subsoil. Similar findings were reported by Majid *et al.* (2012),

Table 43. Effect of foliar application of fortified distillery spentwash on plant height (cm) at different growth stages of tomato crop grown during 2013 and 2014.

Treatments	Plant height (cm)											
	30 DAT			60 DAT			90 DAT			At harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	68.9	62.2	65.6	118.1	105.1	111.6	128.9	118.5	123.7	129.8	123.4	126.6
T₂	68.1	58.6	63.4	116.4	102.2	109.3	124.5	115.7	120.1	125.3	122.5	123.9
T₃	69.0	66.2	67.6	106.8	90.4	98.6	107.6	95.6	101.6	108.5	103.1	105.8
T₄	65.5	62.4	64.0	98.2	85.3	91.8	105.4	91.2	98.3	106.6	96.4	101.5
T₅	66.3	68.5	67.4	95.1	83.0	89.1	101.6	89.7	95.6	102.6	94.2	98.4
T₆	70.1	68.0	69.1	122.7	108.9	115.8	136.4	127.6	132.0	137.4	129.4	133.4
T₇	70.3	64.8	67.6	124.5	112.8	118.6	141.8	129.1	135.5	142.7	132.4	137.6
T₈	70.3	65.8	68.1	113.6	107.0	110.3	132.6	122.6	127.6	133.8	126.6	130.2
T₉	70.0	67.3	68.7	109.1	93.6	101.4	116.9	106.1	111.5	118.1	116.3	117.2
T₁₀	70.4	63.8	67.1	102.9	91.9	97.4	110.1	96.1	103.1	110.9	107.0	109.0
T₁₁	70.5	64.0	67.2	115.2	94.8	105.0	120.3	109.1	114.7	121.4	117.1	119.2
S. Em±	1.37	2.28	1.91	6.22	4.99	5.54	7.27	3.72	5.70	6.87	3.64	5.37
C. D. at 5%	NS	NS	NS	18.36	14.73	15.81	21.45	10.98	16.27	20.27	10.74	15.32
CV (%)	3.44	6.10	4.96	9.70	8.85	9.19	10.45	5.90	8.60	9.79	5.47	7.85

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Further, significantly lower plant height was observed in treatment receiving: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (T₅) during 2013 and 2014 (T₅: 95.1 and 83.0 cm, respectively). This could be due to the fact that SW 1 supplied inadequate quantities of plant nutrients through foliar application. Similar trend of results were observed at 90 DAT and at harvest.

At 60 days after transplanting, pooled analysis of two year experimental results revealed that significantly taller plants (118.6 cm) were observed due to 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) followed by treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (T₆: 115.8 cm), 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval (T₁: 111.6 cm) and 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval (T₈: 110.3 cm). However, significantly lower plant height was observed in T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval during 2013 and 2014 (89.1 cm). Similar trend was observed at 90 DAT and harvest.

Number of branches

The data on number of branches per plant at different growth stages as influenced by foliar application of fortified spentwash are presented in Table 44.

At 30 DAT, branches were not observed in tomato plant. But at 60 DAT, the number of branches per plant showed significant difference with respect to foliar application of fortified distillery spentwash during 2013 and 2014. Significantly higher number of branches was observed during 2013 and 2014 in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇: 7.8 and 7.1 respectively) which were on par with each other. This might be due to the fact that crop received all of the nutrients in adequate quantities through foliar application of fortified spentwash, which in return produced more number of branches per plant. Shah and Saeed (1989) reported that foliar spray of urea increased the number of productive tillers in rice. Similar results have been reported by Sharma *et al.* (2000) using compound liquid fertilizer containing most macro and micro nutrients "Polyfeed and Multi" along with NPK and mentioned that these fertilizers provide nutrients to the plant by foliar application and significant effect on number of branches per plant.

Further, significantly lesser number of branches per plant was observed in treatment T₅ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval during 2013 and 2014 (6.3 and 5.5, respectively). Similar trend was observed at 90 DAT and at harvest.

Table 44. Effect of foliar application of fortified distillery spentwash on number of branches plant⁻¹ at different growth stages of tomato crop grown during 2013 and 2014.

Treatments	Numbers of branches plant ⁻¹								
	60 DAT			90 DAT			At harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	7.1	6.2	6.7	10.7	9.6	10.1	11.0	9.9	10.5
T₂	7.0	6.1	6.6	10.4	9.2	9.8	10.9	9.6	10.3
T₃	6.9	6.0	6.5	9.7	8.2	9.0	9.9	8.6	9.2
T₄	6.6	5.6	6.1	8.8	8.1	8.5	9.1	8.4	8.8
T₅	6.3	5.5	5.9	8.2	8.1	8.2	8.4	8.3	8.3
T₆	7.5	6.9	7.2	11.5	10.4	11.0	11.7	10.6	11.1
T₇	7.8	7.1	7.5	11.8	10.6	11.2	12.0	10.8	11.4
T₈	7.3	6.6	6.9	11.1	10.0	10.6	11.3	10.3	10.8
T₉	6.8	6.0	6.4	10.0	8.7	9.4	10.8	9.0	9.9
T₁₀	6.7	5.9	6.3	9.4	8.5	8.9	9.4	8.8	9.1
T₁₁	7.0	6.1	6.5	9.8	8.8	9.3	10.1	9.3	9.7
S. Em±	0.27	0.31	0.29	0.70	0.28	0.52	0.73	0.29	0.55
C. D. at 5%	0.80	0.93	0.82	2.06	0.82	1.49	2.17	0.84	1.58
CV (%)	6.72	8.81	7.54	11.95	5.29	9.39	12.20	5.25	9.65

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

At 60 days after transplanting, pooled analysis of two year results revealed that significantly higher number of branches (7.5) was noticed due to 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval followed by treatment T₆ receiving 90% RDN through fertilizers + 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (7.2), 90% RDN through fertilizers + 10% RDN through 2 sprays of fortified SW 1 at 30 days interval (T₁: 6.7) and 80% RDN through fertilizers + 20% RDN through 4 sprays of fortified SW 2 at 15 days interval (T₈: 6.9) were on par with each other. However, significantly less number of branches per plant was observed in T₅ which received 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval during 2013 and 2014 (5.9). Similar trend was observed at 90 DAT and harvest.

The higher values of all the growth parameters were noticed due to foliar application of SW 2 (fortified with nitrogen, zinc and boron) than SW 1 (fortified with nitrogen). This might due to the enhancement in photosynthesis and other metabolic activities which led to an increase in various plant metabolites responsible for cell division and elongation resulting in improvement in growth characters. (Hatwar *et al*, 2003).

In general, the number of branches per plant was higher in the crop grown during 2013 compared to the crop grown during 2014.

SPAD chlorophyll meter reading

At 30 DAT, SPAD chlorophyll meter reading did not differ significantly during 2013 and 2014. Since there was no foliar application of fortified spentwash at 30 DAT and all the plots received equal dose of nutrients upto that stage and the treatments were imposed only later.

At 60 DAT, SPAD chlorophyll meter reading showed significant difference with respect to foliar application of fortified distillery spentwash during 2013 and 2014 (Table 45). Significantly higher SPAD chlorophyll meter reading was observed during 2013 and 2014 in the treatment T₇ which received 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇: 24.2 and 20.5, respectively). This might be due to the fact that distillery spentwash contain some amounts of nitrogen, magnesium, iron and zinc which are essential for chlorophyll synthesis and in the present study, the spentwash was further enriched with nitrogen, zinc and boron. These nutrients play an important role in increasing the chlorophyll content. Shilpa Mohan Shitole and Dhumal (2012) reported the beneficial effect of Zn on photosynthetic pigments, which help in increasing the rate of phytochemical reduction in *Lupinus termis* plants. Significantly lower SPAD meter reading was observed in treatment T₁₁ receiving RDF with water spray during 2013 and 2014 (T₁₁: 13.8 and 13.0, respectively). Similar trend was observed at 90 DAT and at harvest.

Table 45. Effect of foliar application of fortified distillery spentwash on SPAD chlorophyll meter (SCMR) reading at different growth stages of tomato crop grown during 2013 and 2014.

Treatments	SPAD chlorophyll meter reading											
	30 DAT			60 DAT			90 DAT			At harvest		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	8.0	7.0	7.5	20.9	17.9	19.4	19.8	17.4	18.6	14.3	13.6	14.0
T₂	8.0	8.1	8.0	20.2	17.3	18.8	18.9	17.0	18.0	13.8	13.5	13.7
T₃	7.9	6.9	7.4	18.0	15.7	16.9	17.3	15.5	16.4	12.9	12.2	12.5
T₄	8.0	8.9	8.4	17.7	15.4	16.6	16.2	15.3	15.8	11.9	11.5	11.7
T₅	8.0	7.3	7.7	15.5	15.3	15.4	15.1	15.1	15.1	11.1	10.8	11.0
T₆	8.1	7.3	7.7	22.9	19.2	21.1	20.3	19.0	19.7	15.1	14.6	14.8
T₇	7.7	7.3	7.5	24.2	20.5	22.3	21.2	20.0	20.6	16.4	14.8	15.6
T₈	8.0	8.0	8.0	21.4	18.5	19.9	20.0	18.3	19.2	14.7	14.1	14.4
T₉	8.2	7.6	7.9	19.1	16.8	18.0	18.4	16.5	17.5	13.5	13.1	13.3
T₁₀	7.9	6.7	7.3	18.9	15.9	17.4	17.8	15.6	16.7	12.6	12.5	12.6
T₁₁	8.0	8.0	8.0	13.8	13.0	13.4	12.4	12.8	12.6	10.6	9.8	10.2
S. Em±	0.25	0.45	0.36	1.77	0.75	1.33	0.79	0.59	0.69	0.91	0.55	0.74
C. D. at 5%	NS	NS	NS	5.23	2.22	3.80	2.33	1.73	1.96	2.67	1.62	2.12
CV (%)	5.37	10.31	8.12	15.87	7.72	12.73	7.61	6.12	6.88	11.76	7.43	9.83

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

At 60 days after transplanting, pooled analysis of two year experimental results revealed that significantly higher SPAD chlorophyll meter reading (22.3) was noticed due to 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval and was on par with the treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (21.1) and 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval (T₈: 19.9). However, significantly lower SPAD meter reading was observed in T₁₃ which received RDF with water spray during 2013 and 2014 (13.4). Similar trend was observed at 90 DAT and harvest.

4.5.2 Yield and yield parameters

The information on per cent fruit set, number of fruits per plant, 10 fruits weight and fruit yield differed significantly due to foliar application of fortified SW 2 (fortified with nitrogen, zinc and boron) compared to SW 1 (fortified with nitrogen) and water sprays during 2013 and 2014 (Tables 46, 47 and 48).

Per cent fruit set

In tomato crop grown during 2013 and 2014, the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval recorded significantly higher per cent fruit set (83.7 & 78.6, respectively) which was on par with treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (82.9 & 77.2). This may be because of the fortified SW 2 supplied some required amount of micronutrients (zinc and boron) to plants through foliar application. Boron plays a major role in plant vital activities such as cell division, leaf and flower bud formation and glucose metabolism and their transport, root growth, cell wall formation and material transportation between cells. While, significantly lower per cent fruit set was recorded in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (64.5 & 63.3 respectively)

The pooled analysis of two years data revealed that the per cent fruit set (Table 46) was significantly higher in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (81.2) which was on par with T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (80.0). Significantly lower per cent fruit set (63.9) was recorded in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Number of fruits per plant

The results pertaining to the effect of fortified spentwash on the number of fruits per plant are presented in Table 46. The higher number of fruits per plant was observed during 2013 than during 2014 (69.3 and 59.4, respectively) in T₇ treatment receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval and was on par with T₆ treatment receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (66.6 and 56.5, respectively).

Table 46. Effect of foliar application of fortified distillery spentwash on per cent fruit set and number of fruits per plant of tomato crop grown during 2013 and 2014.

Treatments	Per cent fruit set			No. of fruits per plant		
	2013	2014	Pooled	2013	2014	Pooled
T ₁	79.6	73.3	76.5	64.7	56.0	60.4
T ₂	77.6	71.7	74.7	62.5	54.9	58.7
T ₃	72.0	66.2	69.1	58.2	50.6	54.4
T ₄	67.8	65.2	66.5	54.1	47.8	51.0
T ₅	64.5	63.3	63.9	50.8	44.0	47.4
T ₆	82.9	77.2	80.0	66.6	56.5	61.5
T ₇	83.7	78.6	81.2	69.3	59.4	64.4
T ₈	80.9	75.3	78.1	62.9	53.6	58.3
T ₉	75.6	68.5	72.0	59.9	52.6	56.3
T ₁₀	72.9	67.7	70.3	54.6	47.0	50.8
T ₁₁	76.8	70.6	73.7	63.8	54.8	59.3
S. Em±	3.80	3.12	3.47	2.74	2.60	2.61
C. D. at 5%	11.21	9.19	9.91	8.09	7.67	7.45
CV (%)	8.69	7.62	8.20	7.82	8.59	8.0

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

This may be because of presence of N, P, K, Ca, Mg, S and some micronutrients and additional quantities supplied through fortification of spentwash which are made available when spentwash is applied to soil through irrigation with water or foliar application. Foliar application of micronutrients enriched spentwash could be useful for improving plant growth, biochemical and physiological activity of crop. The lower number of fruits per plant (50.8 and 44.0, respectively) was recorded in T₅ (70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval) because of lesser nutrient availability. Fortified SW 1 enriched with nitrogen (liquid ammonia) would supply lesser amounts of nutrients through foliar application and there may be some volatilisation losses of ammonia due to high pH 9.12.

Pooled analysis of data of two years (2013 and 2014) revealed that the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval recorded significantly higher number of fruits per plant (64.4) which was on par with treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (61.5). However, significantly lower number of fruits per plant (47.4) was observed in T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Ten fruits weight (g)

The information on ten fruits weight (g) at 2nd and 5th picking varied significantly but at 8th picking it did not differ significantly due to foliar application of fortified distillery spentwash (Table 47).

Significantly higher ten fruits weight (g) at 2nd and 5th picking (1461g and 1345g, respectively) were observed with the treatment T₇ which received 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval compared to all the other treatments and treatment T₇ was on par with treatment T₆ which received 90% RDN through fertilizers + 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (1425g and 1325g respectively) at 2nd and 5th picking during 2013. The same trend was followed in 2014. This may be because of foliar application of spentwash supplies of nitrogen, zinc and boron through enriched spentwash which enhanced individual fruit weight. Anon. (2007) applied a foliar fertilizer “Fetrilon-Combi” (nutrients with water) on chillies and found considerable improvement in fruit development and crop yields as compared to those supplied only with straight chemical fertilizers. Davis *et al.* (2003) also found similar results regarding size of tomato fruit in response to different levels of boron application. Significantly lower ten fruits weight (1221g, 1123g and 1102g, 1043g, respectively during 2013 and 2014) were observed in the treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (T₅).

Table 47. Effect of foliar application of fortified distillery spentwash on weight of ten fruits (g) of tomato grown during 2013 and 2014.

Treatments	10 fruits weight (g)								
	At 2 nd picking			At 5 th picking			At 8 th picking		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	1375	1262	1318	1276	1195	1236	840	725	783
T₂	1357	1250	1304	1251	1137	1194	835	719	777
T₃	1286	1164	1225	1195	1087	1141	776	696	736
T₄	1239	1120	1180	1152	1118	1135	762	685	724
T₅	1221	1102	1162	1123	1043	1083	758	684	721
T₆	1425	1327	1376	1325	1207	1266	872	735	803
T₇	1461	1339	1400	1345	1223	1284	887	738	812
T₈	1405	1315	1360	1302	1197	1249	860	726	793
T₉	1317	1195	1256	1205	1100	1153	784	715	749
T₁₀	1259	1140	1200	1164	1037	1100	770	692	731
T₁₁	1333	1218	1276	1226	1102	1164	827	716	771
S. Em±	47.97	40.84	43.74	38.24	37.88	37.15	31.79	34.1	32.55
C. D. at 5%	141.50	120.48	124.82	112.80	111.74	106.03	NS	NS	NS
CV (%)	6.23	5.79	5.90	5.37	5.80	5.44	6.82	8.34	7.45

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Pooled analysis of two years data of experiments showed significantly higher ten fruits weight (g) at 2nd and 5th picking (1400g and 1284g respectively) was noticed in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval. It was on par with treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (1376g and 1266g respectively). However, significantly lower 10 fruits weight was observed in T₅ (1162g and 1083g respectively) which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Fruit yield (kg plant⁻¹ and t ha⁻¹)

Foliar nutrition of fortified distillery spentwash treatments showed a profound effect in increasing the fruit yield (kg plant⁻¹ and t ha⁻¹) during 2013 and 2014 (Table 48 and Fig. 13). The higher yield was recorded with the application of fortified SW 2 (fortified with nitrogen, zinc and boron) compared to foliar application of SW 1 (fortified with nitrogen) and water spray. Higher fruit yield was recorded in the treatment which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) (8.15, 6.94 kg plant⁻¹ and 89.7, 76.4 t ha⁻¹, respectively). However, it was on par with treatment T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (7.72, 6.75 kg plant⁻¹ and 86.1, 74.0 t ha⁻¹, respectively). Increased yield due to macro and micronutrients application may be attributed to enhanced photosynthetic activity, resulting in increased production and accumulation of carbohydrates and favourable effect on vegetative growth and retention of flower and fruits which might have increased the number of fruits per plant besides improvement in the fruit size. Majid *et al.* (2012) reported that foliar application of nutrients lead to increase in grain yield components and protein per centage in seed; for instance wheat, maize, rice, barley and sorghum showed increase in yield components by application of micronutrients. Boron which enhances the movement of sugar borate complex from the leaves to the fruit and ultimately increased the fruit yield according to result given by Pandita *et al.* (1976) and Singh *et al.* (2003). The results of the present investigation have been further supported by Jiskani (2005), who reported that significant effect on crop yield in chillies was recorded when micronutrients were applied in combination with NPK instead of NPK alone; while Lovatt (2005) indicated that foliar spray of 1 % either Polyfeed or Multi 'K' at 45, 60 and 75 days after planting increased the crop yield by about 10 % over unsprayed control

However, significantly lower fruit yield (6.14, 5.60 kg plant⁻¹ and 67.7, 62.0 t ha⁻¹ respectively) was observed in T₅ treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval. Nitrogen is one of the major element to increase the growth and yield of tomato crop, lower yield was recorded with the treatment T₅ receiving foliar application of 30% RDN through 6 sprays of fortified SW 1 which may be attributed to foliar application of 30% nitrogen (liquid ammonia) enriched spentwash in which volatilisation losses of ammonia might have resulted in lower N content which in turn resulted in lower fruit yield. Parker and Boswell, (1980) reported occurrence of leaf damage due to foliar fertilization sometimes being severe enough to cause yield reductions.

Table 48. Effect of foliar application of fortified distillery spentwash on fruit yield of tomato crop grown during 2013 and 2014.

Treatments	Fruit yield (kg plant ⁻¹)			Fruit yield (t ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled
T₁	7.22	6.63	6.91	79.9	72.8	76.4
T₂	7.01	6.52	6.70	77.6	71.7	74.7
T₃	6.93	6.10	6.52	76.1	67.9	72.0
T₄	6.75	6.01	6.33	73.9	67.0	70.5
T₅	6.14	5.60	5.81	67.7	62.0	64.8
T₆	7.72	6.75	7.24	86.1	74.0	80.0
T₇	8.15	6.94	7.52	89.7	76.4	83.0
T₈	7.32	6.32	6.84	80.7	70.0	75.4
T₉	6.94	6.24	6.65	76.9	69.3	73.1
T₁₀	6.12	5.72	5.91	68.1	63.0	65.6
T₁₁	7.11	6.44	6.72	78.5	70.8	74.7
S. Em±	0.23	0.22	0.22	2.52	2.43	2.47
C. D. at 5%	0.67	0.64	0.63	7.43	7.17	7.05
CV (%)	5.6	6.0	5.8	5.6	6.1	5.8

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

The results of pooled analysis of data of two years (2013 and 2014) revealed that the treatment which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) recorded significantly higher fruit yield (7.52 kg plant⁻¹ and 83.0 t ha⁻¹, respectively) when compared to 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval. (T₅: 5.81 kg plant⁻¹ and 64.8 t ha⁻¹, respectively) but it was on par with the treatment receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (T₆: 7.24 kg plant⁻¹ and 80.0 t ha⁻¹, respectively).

4.5.3 Quality parameters:

The data pertaining to quality parameters such as TSS, ascorbic acid and lycopene content of tomato crop as influenced by foliar application of fortified distillery spentwash are presented in Table 49. Higher desirable quality parameters were recorded due to foliar application of SW 2 (fortified with nitrogen, zinc and boron) compared to SW 1 (fortified with nitrogen) during 2013 and 2014 (Fig.14).

TSS (°Brix)

Significantly higher TSS value was observed during 2013 and 2014 in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (6.4 and 6.1 °Brix, respectively). However, it was on par with treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (6.3 and 5.8 °Brix, respectively), treatment T₁ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval (6.1 and 5.6 °Brix, respectively), treatment T₂ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval (6.1 and 5.5 °Brix, respectively). This could be due to the reason that primary treated distillery spentwash contains high amounts of potassium (K), sulphur (S), nitrogen (N), phosphorus (P) as well as easily biodegradable organic matter and its soil or foliar application has been reported to increase quality of tomato fruits. So foliar spray of these elements is the best method of fertilizer application to control their losses from the soil and make them more and easily available to the plant and which in turn increase the yield and quality of tomato. Similar findings were observed by Zhigulev (1992) who reported that foliar application of nutrients increases the yield and quality of wheat grain. Significantly lower TSS value was observed in treatment T₅ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval during 2013 and 2014 (5.2 and 4.5 °Brix, respectively) because of lesser availability of plant nutrients through 30% foliar spray of SW 1.

Pooled analysis of two years data of experiments showed significantly higher TSS value (6.2 °Brix) in treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval. However, significantly lower TSS value (4.9 °Brix) was observed in T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval during 2013 and 2014 (Table 49).

Ascorbic acid (mg 100⁻¹ g)

The results pertaining to the effect of fortified distillery spentwash on the ascorbic acid content of tomato fruits are presented in Table 49. Increase in the ascorbic acid content of tomato fruits was recorded with the application of SW 2 over SW 1 and water spray during 2013 and 2014. The highest ascorbic acid content of tomato was observed (65.3 and 60.3 mg 100⁻¹ g, respectively) in T₇ treatment which received 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval and was on par with T₆ treatment receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (64.0 and 59.3 mg 100⁻¹, respectively) during 2013 and 2014. Distillery spentwash contain higher amount of nutrients especially potassium. Foliar application of SW 2 resulted in increased vegetative growth of tomato and enhanced nutrients uptake that resulted in increased assimilation rate and resulted in better quality of tomato. These results are in conformity with those of Dube *et al.* (2003).

The lower (45.3 and 43.7 mg 100⁻¹, respectively) ascorbic acid content was recorded in T₅ treatment which received 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval. This could be due to application of excess salts to tomato crop through foliar application of distillery spentwash which affected the quality of fruits.

Pooled analysis of data of two years (2013 and 2014) revealed that the treatment which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) recorded significantly higher ascorbic acid content (62.8mg 100⁻¹). However, significantly lower ascorbic content (44.5mg 100⁻¹) was observed in T₇ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Lycopene (mg 100⁻¹ g)

Foliar application of distillery spentwash fortified with nitrogen, zinc and boron showed a profound effect on increasing in the lycopene content of tomato (mg 100⁻¹ g) during 2013 and 2014 (Table 49). Maximum lycopene content was recorded in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (18.2 and 17.3 mg 100⁻¹ g, respectively). It was on par with treatment T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (17.2 and 16.8 mg 100⁻¹ g, respectively). This could be due to manurial effect of distillery spentwash. Distillery spentwash contains appreciable amount of nutrients especially potassium which is vital for improving quality of tomato and also potassium is very important in the overall metabolism of plant. In addition, it has a beneficial effect on water consumption. Also, potassium is involved in a number of steps in protein synthesis. Zinc also play a vital role in improving the quality of fruits, as zinc takes part in photosynthesis, chlorophyll, metabolism of starch formation and carbohydrate formation, the maximum requirements of Zn were enough to accumulate suitable carbohydrate contents. The results are in conformity with the findings of Singh (2001).

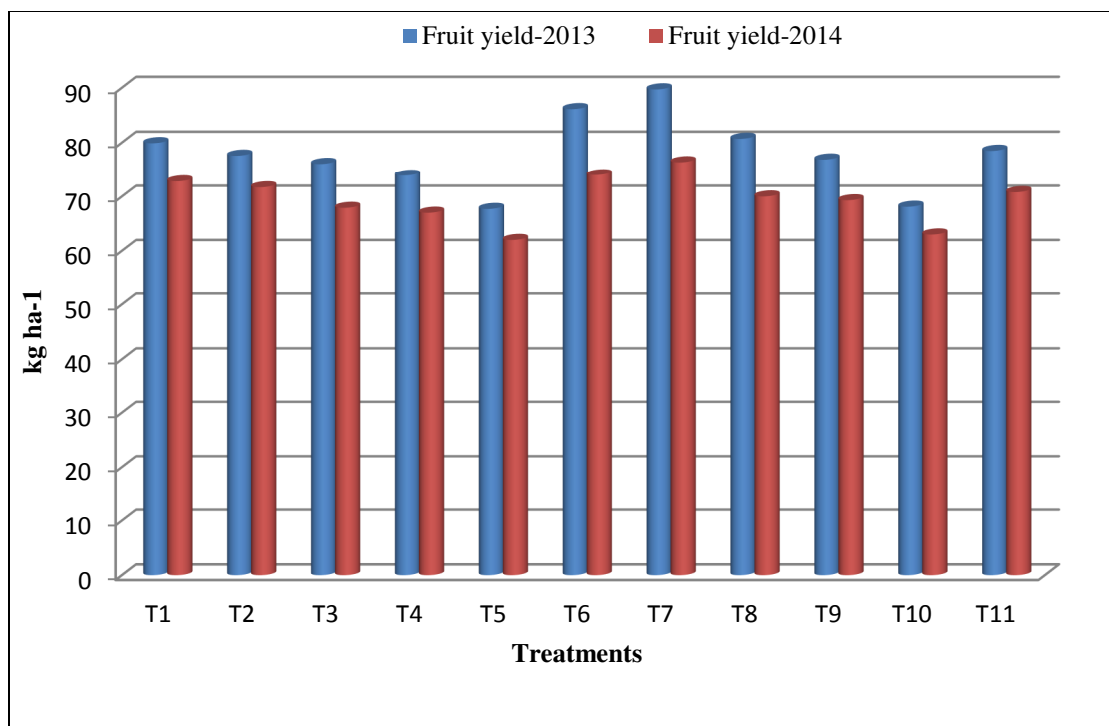


Fig. 13: Fruit yield of tomato grown during 2013 and 2014 as influenced by foliar application of fortified distillery spentwash

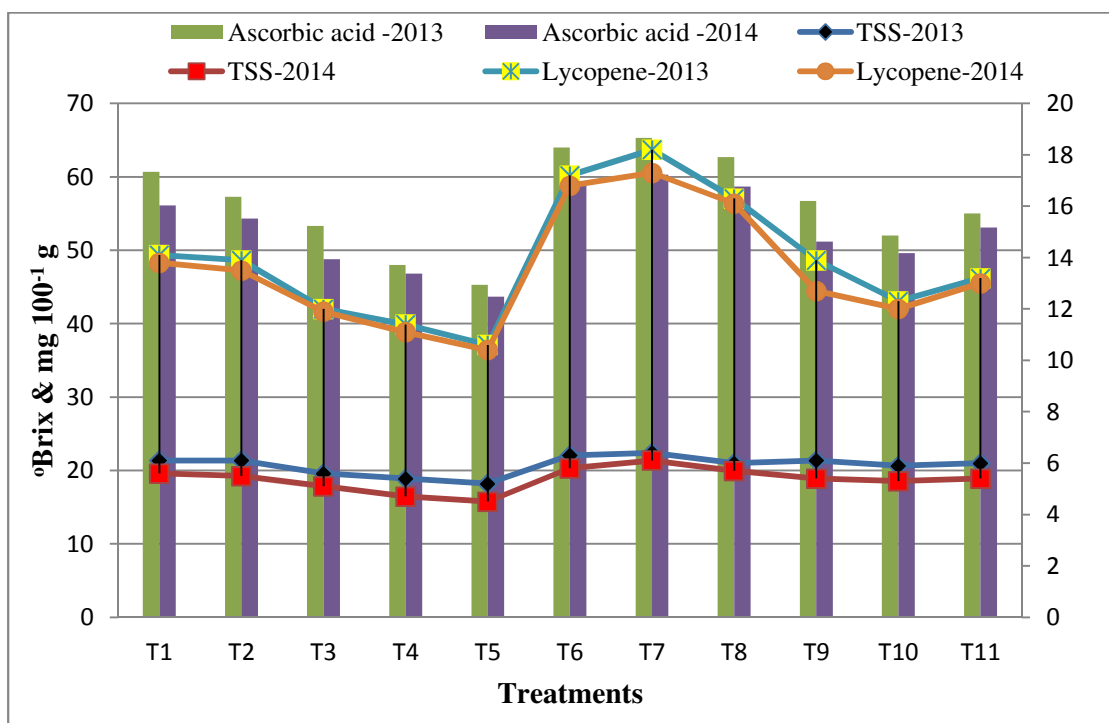


Fig. 14: Quality parameters of tomato grown during 2013 and 2014 as influenced by foliar application of diluted distillery spentwash



Plate 5: General view of field experiment-II

Table 49. Effect of foliar application of fortified distillery spentwash on TSS, ascorbic acid and lycopene content of tomato fruits.

Treatments	TSS (°Brix)			Ascorbic acid (mg 100 ⁻¹ g)			Lycopene (mg 100 ⁻¹ g)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	6.1	5.6	5.8	60.7	56.1	58.4	14.1	13.8	13.9
T ₂	6.1	5.5	5.8	57.3	54.3	55.8	13.9	13.5	13.7
T ₃	5.6	5.1	5.4	53.3	48.8	51.1	12.0	11.9	11.9
T ₄	5.4	4.7	5.1	48.0	46.8	47.4	11.4	11.1	11.3
T ₅	5.2	4.5	4.9	45.3	43.7	44.5	10.6	10.4	10.5
T ₆	6.3	5.8	6.1	64.0	59.1	61.5	17.2	16.8	17.0
T ₇	6.4	6.1	6.2	65.3	60.3	62.8	18.2	17.3	17.7
T ₈	6.0	5.7	5.9	62.7	58.7	60.7	16.3	16.1	16.2
T ₉	6.1	5.4	5.8	56.7	51.2	54.0	13.9	12.7	13.3
T ₁₀	5.9	5.3	5.6	52.0	49.6	50.8	12.3	12.0	12.1
T ₁₁	6.0	5.4	5.7	55.0	53.1	54.1	13.2	13.0	13.1
S. Em±	0.10	0.25	0.19	2.93	3.22	3.05	0.78	0.43	0.64
C. D. at 5%	0.30	0.74	0.55	8.64	9.49	8.70	2.30	1.28	1.81
CV (%)	3.01	8.06	5.96	9.00	10.54	9.66	9.72	5.56	8.03

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

However, significantly lower lycopene content (10.6 and 10.4 mg 100⁻¹ g, respectively) was observed in T₅ treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

The results of pooled analysis of data of two years (2013 and 2014) revealed that the treatment which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) recorded significantly higher lycopene content of tomato (17.7 mg 100⁻¹ g) when compared to all the other treatments and it was on par with treatment T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (17.0 mg 100⁻¹ g, respectively) However, significantly lower lycopene content was observed in treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval. (T₅:10.5 mg 100⁻¹ g).

Foliar application of SW 2 (fortified with nitrogen, zinc and boron) recorded higher quality parameters of tomato compared to SW 1 (fortified with nitrogen). Increase in quality parameter might be due to the growth promoting substances which could have accelerated synthesis of carbohydrate, vitamins and other quality characters. These results are in conformity with those of Fagaria *et al.* (1992). Rajput *et al.* (1995) who reported that zinc is involved in key metabolic processes such as respiration, photosynthesis and assimilation of some major nutrients. Zinc plays an important role in enzymes activation as well. The efficiency of such type of elements is improved when it is used in combination with other elements like N and K.

The spentwash contains 1% of potassium (K), which is one of the important sources for improving the quality of tomato and it is involved in growth of meristematic tissue and is indispensable for the maintenance of cell turgor pressure, which is required for cell expansion. The use of K is especially important where high rate of nitrogen and phosphorus is used and when high yield and quality is expected (Narang *et al.*, 1997).

4.5.4 Nutrient concentration of whole tomato plant at 80 DAT

The data on concentration of nitrogen, phosphorus and potassium by tomato crop (whole plant) varied significantly due to foliar application of fortified (fortified with nitrogen, zinc and boron) distillery spentwash during 2013 and 2014 at 80 days after transplanting (Table 50). Foliar application of SW 2 (fortified with nitrogen, zinc and boron) recorded higher nutrient concentration and nutrient uptake in tomato plant compared to SW 1 (fortified with nitrogen). During both the years (2013 and 2014) nitrogen, phosphorus and potassium concentration in tomato plant at 80 DAT was significantly higher in T₇ treatment that received 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (2.64, 0.76, 2.98 % and 2.20, 0.62, 2.33 %, respectively) compared treatment T₅ which received 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (2.16, 0.48, 2.52 and 1.67, 0.30, 1.87 %).

Table 50. Effect of foliar application of fortified distillery spentwash on primary nutrients content (at 80 DAT) of whole tomato plant grown during 2013 and 2014.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	2.48	1.98	2.23	0.67	0.51	0.59	2.81	2.16	2.49
T₂	2.42	1.94	2.18	0.65	0.48	0.57	2.76	2.11	2.44
T₃	2.30	1.81	2.06	0.55	0.38	0.47	2.64	1.99	2.32
T₄	2.20	1.70	1.95	0.51	0.33	0.42	2.56	1.91	2.24
T₅	2.16	1.67	1.92	0.48	0.30	0.39	2.52	1.87	2.20
T₆	2.60	2.15	2.38	0.73	0.57	0.67	2.92	2.27	2.60
T₇	2.64	2.20	2.42	0.76	0.62	0.68	2.98	2.33	2.66
T₈	2.55	2.09	2.32	0.71	0.55	0.63	2.86	2.21	2.54
T₉	2.34	1.86	2.10	0.58	0.41	0.50	2.67	2.02	2.35
T₁₀	2.25	1.75	2.00	0.52	0.34	0.43	2.60	1.95	2.28
T₁₁	2.38	1.90	2.14	0.63	0.47	0.55	2.70	2.05	2.38
S. Em±	0.03	0.02	0.03	0.03	0.02	0.02	0.09	0.07	0.08
C. D. at 5%	0.10	0.07	0.08	0.08	0.07	0.07	0.25	0.19	0.22
CV (%)	2.36	2.11	2.46	6.55	8.97	7.45	5.46	5.43	5.45

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Pooled analysis of data of two years (2013 and 2014) revealed that the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval recorded significantly higher concentration of nitrogen, phosphorus and potassium (N: 2.42 %, P: 0.68 % and K: 2.66 %, respectively) in tomato plant at 80DAT compared to all the other treatments and it was on par with treatment T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (N: 2.38 %, P: 0.67 % and K: 2.60 %, respectively) However, significantly lower concentration of nitrogen, phosphorus and potassium (N: 1.92 %, P: 0.39% and K: 2.20 %, respectively) in tomato plant at 80DAT was observed in T₅ treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

The data on concentration of calcium, magnesium and sulphur in whole tomato plant varied significantly due to foliar application of fortified distillery spentwash (Table 51). The concentration of calcium, magnesium and sulphur was lower in whole tomato plant at 80 DAT during 2014 compared to 2013.

The concentration of calcium, magnesium and sulphur in whole tomato plant differed significantly due to foliar application of fortified distillery spentwash at 80 days after transplanting (Table 51). Application of 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) recorded significantly higher concentration of calcium, magnesium and sulphur (Ca: 0.65, 0.59 %, Mg: 0.41, 0.38 % and S: 0.48, 0.42 %, respectively) in whole tomato plant compared to all the other treatments. It was on par with treatment T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (Ca: 0.63, 0.57 %, Mg: 0.38, 0.36 % and S: 0.44, 0.40 %,) Significantly lower concentrations of calcium, magnesium and sulphur in whole tomato plant (Ca: 0.44, 0.31 %, Mg: 0.25, 0.15 % and S: 0.23, 0.16 %, respectively) were observed in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Pooled analysis of two years of experiment data revealed that the Ca, Mg and S concentration in whole tomato plant varied significantly due to treatments at 80 days after transplanting. Higher concentration of Ca, Mg and S was observed in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (0.62, 0.40 and 0.45 %, respectively) compared to the other treatments. Significantly lower concentration was recorded in the treatment T₅ which received 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (0.38, 0.20 and 0.20 %, respectively).

The concentration of micronutrients in whole tomato plant at 80 DAT as influenced by foliar application of fortified (fortified with nitrogen, zinc and boron) distillery spentwash at 80 days after transplanting is presented in Table 52.

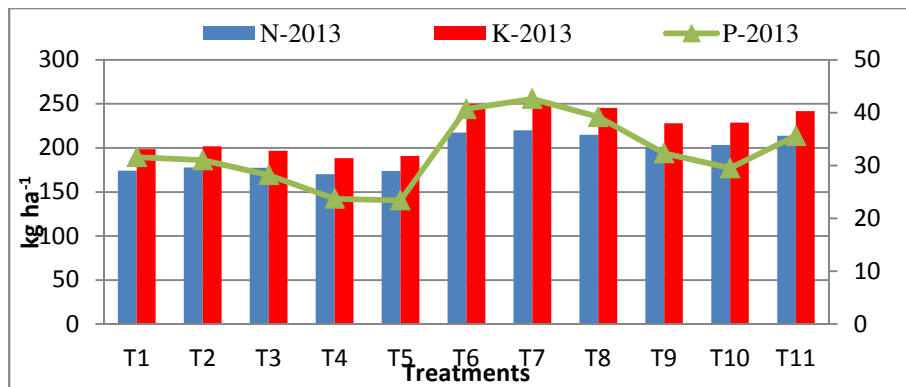


Fig. 15: Primary nutrient uptake by tomato crop grown during 2013 as influenced by foliar application of fortified distillery spentwash

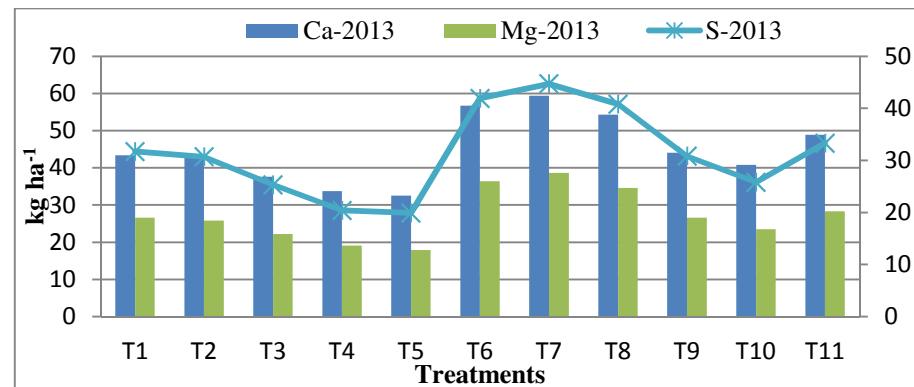


Fig. 16: Secondary nutrient uptake by tomato crop grown during 2013 as influenced by foliar application of fortified distillery spentwash

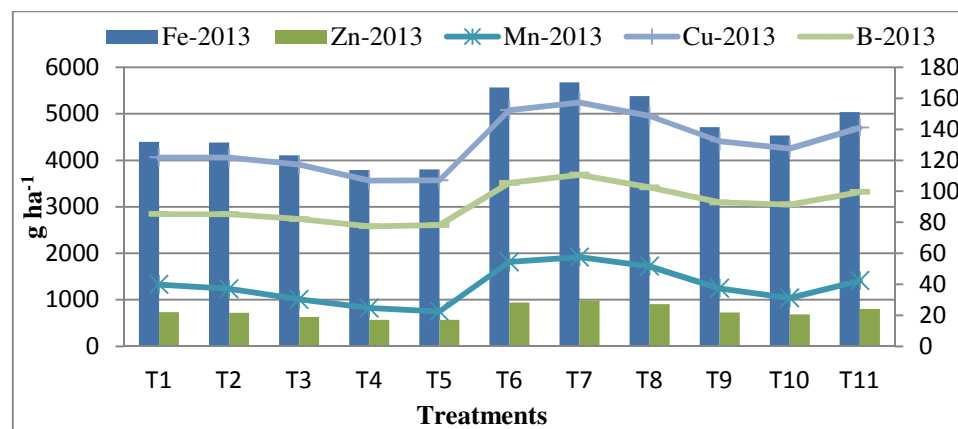


Fig. 17: Micronutrient uptake by tomato crop grown during 2013 as influenced by foliar application of fortified distillery spentwash

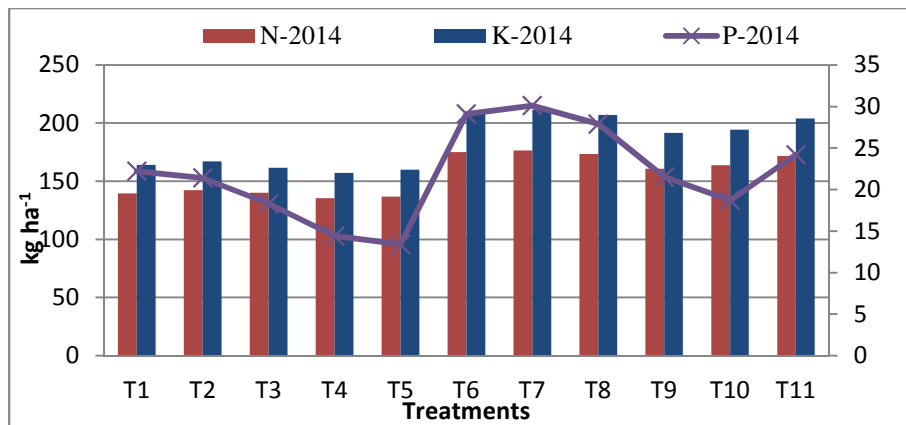


Fig. 18: Primary nutrient uptake by tomato crop grown during 2014 as influenced by foliar application of fortified distillery spentwash

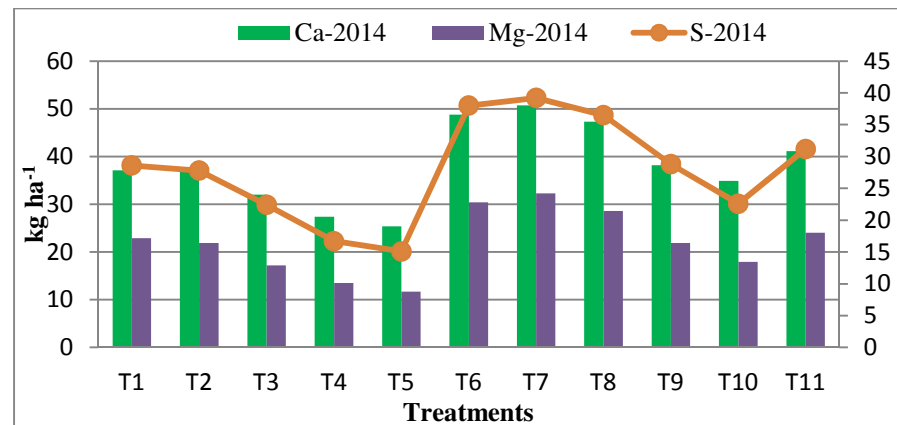


Fig. 19: Secondary nutrient uptake by tomato crop grown during 2014 as influenced by foliar application of fortified distillery spentwash

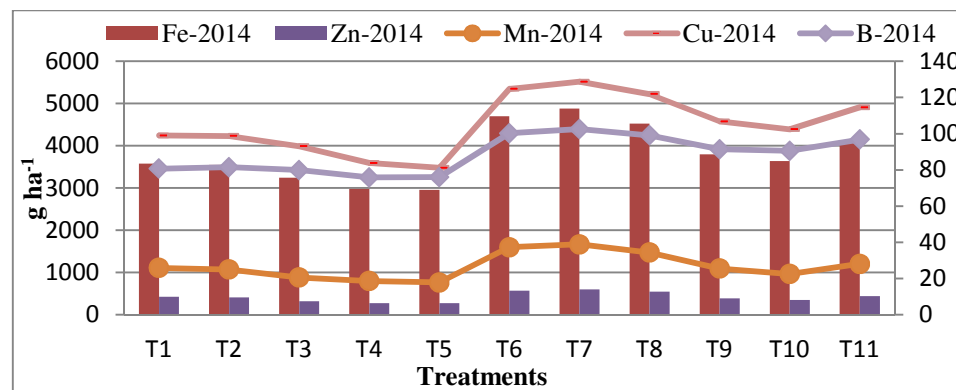


Fig. 20: Micronutrient uptake by tomato crop grown during 2014 as influenced by foliar application of fortified distillery spentwash

Table 51. Effect of foliar application of fortified distillery spentwash on secondary nutrients content (at 80 DAT) of whole tomato plant grown during 2013 and 2014.

Treatments	Calcium (%)			Magnesium (%)			Sulphur (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	0.58	0.51	0.55	0.35	0.32	0.34	0.40	0.34	0.37
T ₂	0.56	0.48	0.52	0.34	0.29	0.32	0.38	0.33	0.36
T ₃	0.49	0.38	0.44	0.29	0.22	0.26	0.32	0.24	0.28
T ₄	0.46	0.32	0.39	0.27	0.18	0.23	0.26	0.17	0.22
T ₅	0.44	0.31	0.38	0.25	0.15	0.20	0.23	0.16	0.20
T ₆	0.63	0.57	0.60	0.38	0.36	0.37	0.44	0.40	0.42
T ₇	0.65	0.59	0.62	0.41	0.38	0.40	0.48	0.42	0.45
T ₈	0.60	0.54	0.57	0.37	0.34	0.36	0.41	0.36	0.39
T ₉	0.50	0.42	0.46	0.31	0.26	0.29	0.35	0.27	0.31
T ₁₀	0.47	0.35	0.41	0.28	0.20	0.24	0.28	0.20	0.24
T ₁₁	0.52	0.45	0.49	0.32	0.27	0.30	0.37	0.29	0.33
S. Em±	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.01	0.01
C. D. at 5%	0.05	0.06	0.05	0.08	0.06	0.05	0.07	0.03	0.03
CV (%)	5.62	7.23	6.13	14.33	12.39	10.72	11.35	6.34	6.27

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 52. Effect of foliar application of fortified distillery spentwash on micronutrients content (at 80 DAT) of whole tomato plant grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(g ha ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	648.3	601.2	624.8	367.2	330.1	348.7	87.2	68.2	77.7	18.7	15.0	16.9	11.2	10.1	10.7
T₂	640.2	586.2	613.2	360.1	295.6	327.9	85.4	66.4	75.9	18.3	14.7	16.5	11.0	9.8	10.4
T₃	586.3	540.2	563.3	328.6	248.6	288.6	74.2	56.2	65.2	17.1	13.4	15.3	9.9	9.2	9.6
T₄	548.2	496.2	522.2	301.2	232.5	266.9	66.8	48.8	57.8	16.2	12.5	14.4	9.4	9.0	9.2
T₅	531.0	486.9	509.0	289.2	213.5	251.4	62.8	42.8	52.8	15.8	11.2	13.5	9.2	8.7	8.9
T₆	675.2	632.1	653.7	381.2	324.5	352.9	93.1	74.1	83.6	19.6	16.4	18.0	12.2	10.9	11.5
T₇	698.2	645.2	671.7	390.2	338.1	364.2	96.5	76.5	86.5	20.1	16.9	18.5	12.9	11.5	12.2
T₈	658.3	618.2	638.3	378.6	318.2	348.4	91.4	72.4	81.9	19.2	16.0	17.6	11.8	10.5	11.2
T₉	602.4	555.2	578.8	341.2	267.6	304.4	78.6	59.1	68.9	17.6	14.1	15.9	10.6	9.4	10.0
T₁₀	572.3	518.2	545.3	314.2	234.2	274.2	70.5	51.5	61.0	16.8	13.4	15.1	9.8	9.1	9.4
T₁₁	620.1	562.3	591.2	342.8	272.5	307.7	82.1	63.1	72.6	18.0	14.6	16.3	10.6	9.5	10.1
S. Em±	23.42	23.99	23.55	17.41	17.41	16.99	2.34	2.34	2.28	0.23	0.20	0.20	0.39	0.31	0.51
C. D. at 5%	69.08	70.79	67.23	51.35	51.35	48.48	6.89	6.89	6.50	0.69	0.59	0.58	1.15	0.92	1.45
CV (%)	6.58	7.32	6.89	8.74	10.78	9.42	5.01	6.55	5.54	2.25	2.41	2.3	6.25	5.52	8.59

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval
T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

In general the concentration of all the micronutrients was higher in whole tomato plant grown during 2013 compared to 2014. Significantly higher concentration of Fe, Mn, Zn, Cu, and B were observed in treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (698.2, 390.2, 96.5, 20.1, 12.9 mg kg⁻¹ and 645.2, 338.1, 76.5, 16.9, 11.5 mg kg⁻¹, respectively) compared to all the other treatments during 2013 and 2014. However, lower Fe, Mn, Zn, Cu, and B contents were recorded in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (531.0, 289.2, 62.8, 15.8, 9.2 mg kg⁻¹ and 486.9, 213.5, 42.8, 11.2, 8.70 mg kg⁻¹, respectively) during 2013 and 2014.

The pooled analysis of two years data revealed that the concentrations of Fe, Mn, Zn, Cu, and B in whole tomato plant varied significantly due to foliar application of fortified distillery spentwash. Higher concentration of Fe, Mn, Zn, Cu, and B were recorded in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (671.7, 364.2, 86.5, 18.5, 12.2 mg kg⁻¹) compared to all the other treatments. However, lower concentration of Zn, B, Fe, Mn and Cu was recorded in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (509.0, 251.4, 52.8, 13.5, 8.9 mg kg⁻¹, respectively).

4.5.5 Nutrient uptake by whole tomato plant at 80 DAT

The data pertaining to nitrogen, phosphorus and potassium uptake by whole tomato plant differed significantly due to foliar application of fortified distillery spentwash at 80 days after transplanting (Table 53).

The nitrogen, phosphorus and potassium uptake by whole tomato plant at 80 days after transplanting was lower in SW 1 (fortified with nitrogen) treatment compared to SW 2 (fortified with nitrogen, zinc and boron) treatments. Significantly higher nitrogen, phosphorus and potassium uptake by whole tomato plant at 80 days after transplanting was recorded in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval during 2013 and 2014 (N: 130.3, 99.1, P: 36.3, 27.9 and K: 147.1, 105.0 kg ha⁻¹, respectively). The higher phosphorus uptake by tomato crop could be due to the fact that nearly 70 to 80 per cent of the phosphorus applied through conventional fertilizers may get fixed up in the soil but in case of the foliar-added phosphorus, nearly 80 per cent of applied phosphorus is directly absorbed through leaves by plants. However, lower nitrogen, phosphorus and potassium uptake by whole tomato plant was recorded in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval during 2013 and 2014 (N: 71.2, 40.2, P: 15.8, 7.2 and K: 83.0, 45.0 kg ha⁻¹, respectively).

Table 53. Effect of foliar application of fortified distillery spentwash on primary nutrients uptake (at 80 DAT) by tomato crop grown during 2013 and 2014.

Treatments	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	101.0	67.6	84.3	27.3	17.4	22.3	114.4	73.7	94.1
T₂	93.4	63.5	78.4	25.1	15.7	20.4	106.5	69.0	87.8
T₃	83.4	54.1	68.8	19.9	11.4	15.7	95.7	59.5	77.6
T₄	75.3	44.2	59.7	17.4	8.6	13.0	87.6	49.7	68.6
T₅	71.2	40.2	55.7	15.8	7.2	11.5	83.0	45.0	64.0
T₆	124.1	87.3	105.7	36.0	23.1	29.7	139.4	92.1	115.8
T₇	130.3	99.1	114.7	36.3	27.9	32.0	147.1	105.0	126.0
T₈	112.0	77.6	94.8	31.2	20.4	25.8	125.6	82.0	103.8
T₉	86.2	57.2	71.7	21.4	12.6	17.0	98.4	62.1	80.3
T₁₀	79.8	49.4	64.6	18.4	9.6	14.0	92.2	55.1	73.7
T₁₁	89.6	61.1	75.3	23.7	15.1	19.4	101.6	65.9	83.8
S. Em±	3.40	2.55	2.99	0.90	0.64	0.77	3.87	2.74	3.34
C. D. at 5%	10.04	7.52	8.54	2.65	1.88	2.21	11.41	8.09	9.53
CV (%)	6.20	6.93	6.53	6.28	7.18	6.74	6.19	6.88	6.55

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

From the results of pooled analysis of data of two years (2013 and 2014), significantly higher nitrogen, phosphorus and potassium uptake by whole tomato plant at 80 days after transplanting (114.7, 32.0 and 126.0 kg ha⁻¹, respectively) was noticed due to 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇). It was on par with T₆ treatment receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (105.7, 29.7 and 115.8 kg ha⁻¹). However, significantly lower nitrogen, phosphorus and potassium uptake by whole tomato plant was noticed in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (T₅: 55.7, 11.5 and 64.0 kg ha⁻¹, respectively). The nitrogen, phosphorus and potassium uptake by whole tomato plant at 80 days after transplanting was lower during 2014 compared to 2013

The information on uptake of calcium, magnesium and sulphur by whole tomato plant at 80 days after transplanting differed significantly due to foliar application of fortified distillery spentwash (Table 54).

Uptake of calcium, magnesium and sulphur by whole tomato plant was relatively lower during 2014 compared to 2013. Higher uptake of calcium, magnesium and sulphur by whole tomato plant was recorded in treatment T₇ receiving 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (32.1, 20.2, 23.7 kg ha⁻¹ and 26.6, 17.1, 18.9 kg ha⁻¹) during 2013 and 2014 respectively. However, lower uptake of calcium, magnesium and sulphur (14.5, 8.20, 7.62 kg ha⁻¹ and 7.50, 4.10, 3.82 kg ha⁻¹, respectively) was recorded in the treatment T₅ receiving 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

The results of pooled analysis of two years data (2013 and 2014) revealed that significantly higher uptake of Ca, Mg and S (29.3, 18.6 and 21.3 kg ha⁻¹, respectively) by whole tomato plant compared to all the other treatments was observed in T₇ treatment receiving 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval and was on par with treatment T₆ which received 90% RDN through fertilizers + 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (26.6, 16.3 and 18.6 kg ha⁻¹, respectively). However, significantly lower uptake of Ca, Mg and S by whole tomato plant (11.0, 6.16 and 5.76 kg ha⁻¹, respectively) was observed in the treatment T₅ which received 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

The results on uptake of Fe, Mn, Zn, Cu, and B by whole tomato plant at 80 days after transplanting varied significantly due to foliar application of fortified distillery spentwash (Table 55).

Table 54. Effect of foliar application of fortified distillery spentwash on secondary nutrients uptake (at 80 DAT) by tomato crop grown during 2013 and 2014

Treatments	Calcium (kg ha ⁻¹)			Magnesium (kg ha ⁻¹)			Sulphur (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	23.6	17.4	20.5	15.5	10.9	13.2	16.3	11.6	13.9
T ₂	21.6	15.7	18.7	13.1	9.52	11.3	14.7	10.8	12.7
T ₃	17.8	11.4	14.6	10.5	6.64	8.55	11.6	7.22	9.40
T ₄	15.7	8.30	12.0	9.20	4.70	6.96	8.91	4.40	6.72
T ₅	14.5	7.50	11.0	8.20	4.10	6.16	7.62	3.82	5.76
T ₆	30.1	23.1	26.6	18.1	14.6	16.3	21.0	16.2	18.6
T ₇	32.1	26.6	29.3	20.2	17.1	18.6	23.7	18.9	21.3
T ₈	26.3	20.0	23.2	16.2	12.6	14.4	18.0	13.4	15.7
T ₉	18.4	12.9	15.7	11.4	8.0	9.71	12.9	8.36	10.6
T ₁₀	16.7	9.90	13.3	9.82	5.70	7.79	9.90	5.71	7.82
T ₁₁	19.6	14.5	17.0	12.0	8.76	10.3	13.9	9.37	11.6
S. Em±	0.77	0.63	0.70	0.48	0.39	0.43	0.53	0.42	0.47
C. D. at 5%	2.27	1.85	1.99	1.40	1.14	1.22	1.57	1.23	1.35
CV (%)	6.20	7.14	6.62	6.26	7.18	6.61	6.39	7.23	6.72

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 55. Effect of foliar application of fortified distillery spentwash on micronutrients uptake at (80 DAT) by tomato crop grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(g ha ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	2639	2052	2346	1495	1127	1311	355.0	232.8	293.9	76.1	51.2	63.7	45.6	34.5	40.0
T ₂	2471	1917	2194	1390	967	1178	329.6	217.2	273.4	70.6	48.0	59.3	42.5	31.9	37.2
T ₃	2125	1616	1871	1191	744	967	269.0	168.1	218.5	62.0	40.1	51.0	36.0	27.6	31.8
T ₄	1876	1290	1583	1031	604	817	228.6	126.9	177.7	55.4	32.5	44.0	32.2	23.3	27.7
T ₅	1750	1171	1460	953	513	733	206.9	102.9	154.9	52.1	26.9	39.5	30.1	20.9	25.5
T ₆	3223	2565	2894	1820	1317	1568	444.4	300.7	372.6	93.6	66.6	80.1	58.2	44.1	51.2
T ₇	3446	2906	3176	1926	1523	1724	476.2	344.6	410.4	99.2	76.1	87.7	63.7	51.8	57.7
T ₈	2891	2294	2592	1663	1181	1422	401.4	268.7	335.0	84.3	59.4	71.8	51.8	39.0	45.4
T ₉	2220	1708	1964	1257	823	1040	289.6	181.8	235.7	64.8	43.4	54.1	39.1	29.0	34.0
T ₁₀	2030	1464	1747	1114	662	888	250.0	145.5	197.8	59.6	37.9	48.7	34.8	25.6	30.2
T ₁₁	2334	1808	2071	1290	876	1083	309.1	202.9	256.0	67.8	46.9	57.4	39.9	30.6	35.3
S. Em±	88.49	75.77	81.86	49.60	38.00	43.92	11.77	8.58	10.24	2.56	1.94	2.26	1.54	1.29	1.41
C. D. at 5%	261.06	223.52	233.62	146.33	112.10	125.34	34.72	25.30	29.22	7.57	5.72	6.45	4.54	3.80	4.03
CV (%)	6.24	6.94	6.53	6.25	7.00	6.57	6.30	7.13	6.7	6.22	6.99	6.56	6.19	6.85	6.47

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

The uptake of micronutrients by whole tomato plant in general was lower in treatments SW 1 compared to SW 2 treatments. Higher uptake of Fe, Mn, Zn, Cu, and B were recorded in treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (3446, 1926, 476.2, 99.2, 63.7 g ha⁻¹ compared to all the other treatments during 2013 and similar trend was followed in 2014. However, lower uptake of Fe, Mn, Zn, Cu, and B (1750, 953.0, 206.9, 52.1, 30.1 g ha⁻¹ and 1171, 513.0, 102.9, 26.9, 20.9 g ha⁻¹, respectively) was observed in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Pooled analysis of data of two years (2013 and 2014) showed significantly higher uptake of Fe, Mn, Zn, Cu, and B by whole tomato plant in the treatment T₇ that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (3176, 1724, 410.4, 87.7, 57.7 g ha⁻¹) that was on par with treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (2894, 1568, 372.6, 80.1, 51.2 g ha⁻¹, respectively). Lower uptake of Fe, Mn, Zn, Cu, and B by whole tomato plant was observed in T₅ treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (1460, 733.0, 154.9, 39.5, 25.5g ha⁻¹ respectively).

Significantly higher concentration and uptake of cations (Ca, Mg and K) and anions (N, P and S) by the whole tomato crop was observed at 80 DAT during 2013 and 2014 with the foliar application of fortified (SW 2 compared to SW 1) distillery spentwash (Table 24 to 29). Significantly higher concentration and uptake of all the nutrients were observed in treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days intervals. This is because nitrogen, zinc and boron along with potassium and other nutrients supplied through fortified spentwash helps to enhance the biomass of the crop, there by increased concentration and uptake of cations and anions. The foliar application of nutrients is more effective as compared to soil applied nutrients because of effective utilization as they are easily absorbed by plants (Narang *et al.*, 1997). Increase in dry matter production of fruits by foliar application of SW may be attributed to greater accumulation of photosynthates by vegetative parts and its subsequent translocation to the sink. Also boron play a role in enhancing the movement of sugar borate complex from the leaves to the fruit and ultimately increase the nutrient uptake by fruits and fruit yield according to the results of Pandita *et al.* (1976); Singh *et al.* (2003). Increase in uptake of nutrients may also be due to higher nutrient content coupled with better vegetative growth in these treatments. Results of enhanced uptake of nutrients due to the application of raw spentwash was reported by Gomez (1996) and Mahendra (2007). Micronutrients are not only essential for better growth, yield and quality, but also important like other major nutrients in spite of their requirement in micro quantity. They also help in uptake of major nutrients and also are vital to the growth of plants by acting as catalysts in promoting various organic reactions during cell development to respiration, photosynthesis, chlorophyll formation, enzyme activity, hormones synthesis and nitrogen fixation. These results are in accordance with the findings of Gupta *et al.* (2001).

However, significantly lower concentration and uptake of cations and anions were observed in the treatment T₅ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval during both years. This may be due to less availability of nitrogen due to volatilisation losses of applied nitrogen resulting in decreased uptake of nutrients and growth of the crop.

4.5.6 Nutrient concentration in tomato fruits at harvest

The concentration of nitrogen, phosphorus and potassium in tomato fruits varied significantly due to foliar application of fortified (with nitrogen, zinc and boron) distillery spentwash at harvest (Table 56). The concentration of nitrogen, phosphorus and potassium was higher in tomato fruit grown during 2013 compared to 2014.

Nitrogen, phosphorus and potassium concentration in tomato fruit was significantly higher in T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (2.58, 0.44, 2.90 % and 2.18, 0.31, 2.60 %) compared to all the other treatments during 2013 and 2014, respectively. However, lower nitrogen, phosphorus and potassium concentration was noticed in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (2.30, 0.28, 2.49 and 1.85, 0.16, 2.20 %) during 2013 and 2014 respectively.

The pooled analysis of two years data revealed that the concentration of N, P and K in tomato fruit was significantly higher in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (2.30, 0.38 and 2.75 %, respectively). Significantly lower concentration of N, P and K was recorded in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (2.06, 0.22 and 2.35 %, respectively) during 2013 and 2014.

The data presented in Table 57 showed that the concentration of calcium, magnesium and sulphur in tomato fruit varied significantly due to foliar application of fortified distillery spentwash at harvest. The concentration of calcium, magnesium and sulphur in tomato fruit was higher due to foliar application of SW 2 (fortified with nitrogen, zinc and boron) compared to SW 1 (fortified with nitrogen) during 2013 than 2014.

Pooled analysis indicated that the Ca, Mg and S concentration in tomato fruit varied significantly due to treatments. Higher concentration of Ca, Mg and S was observed in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (0.59, 0.38 and 0.42 %, respectively) compared to other treatments. It was on par with treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (0.56, 0.36 and 0.41 %, respectively). Significantly lower concentration of Ca, Mg and S was recorded in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (0.36, 0.19 and 0.23 %, respectively).

Table 56. Effect of foliar application of fortified distillery spentwash on primary nutrients content at harvest of tomato fruit grown during 2013 and 2014.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	2.48	2.05	2.22	0.40	0.28	0.34	2.78	2.48	2.63
T₂	2.46	2.02	2.20	0.38	0.26	0.32	2.74	2.44	2.59
T₃	2.40	1.95	2.13	0.34	0.22	0.28	2.57	2.27	2.42
T₄	2.34	1.92	2.09	0.29	0.17	0.23	2.54	2.24	2.39
T₅	2.30	1.85	2.06	0.28	0.16	0.22	2.49	2.20	2.35
T₆	2.55	2.14	2.28	0.42	0.30	0.36	2.86	2.56	2.71
T₇	2.58	2.18	2.30	0.44	0.31	0.38	2.90	2.60	2.75
T₈	2.52	2.09	2.25	0.41	0.29	0.35	2.82	2.52	2.67
T₉	2.43	1.98	2.15	0.35	0.23	0.29	2.68	2.38	2.53
T₁₀	2.36	1.93	2.12	0.31	0.19	0.25	2.62	2.32	2.47
T₁₁	2.44	2.01	2.18	0.37	0.25	0.31	2.71	2.41	2.56
S. Em±	0.03	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.05
C. D. at 5%	0.09	0.05	0.07	0.09	0.10	0.09	0.13	0.16	0.14
CV (%)	2.21	1.55	1.98	5.16	4.65	4.90	2.87	3.85	3.34

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 57. Effect of foliar application of fortified distillery spentwash on secondary nutrients content at harvest of tomato fruit grown during 2013 and 2014.

Treatments	Calcium (%)			Magnesium (%)			Sulphur (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	0.54	0.48	0.51	0.34	0.30	0.32	0.40	0.35	0.38
T₂	0.53	0.46	0.50	0.33	0.28	0.31	0.38	0.37	0.37
T₃	0.45	0.40	0.43	0.27	0.22	0.25	0.31	0.29	0.30
T₄	0.42	0.35	0.39	0.24	0.18	0.21	0.26	0.22	0.24
T₅	0.39	0.32	0.36	0.22	0.15	0.19	0.25	0.20	0.23
T₆	0.59	0.53	0.56	0.38	0.33	0.36	0.43	0.38	0.41
T₇	0.61	0.56	0.59	0.40	0.35	0.38	0.44	0.40	0.42
T₈	0.56	0.51	0.54	0.37	0.31	0.34	0.41	0.37	0.39
T₉	0.48	0.42	0.45	0.29	0.25	0.27	0.34	0.31	0.33
T₁₀	0.43	0.38	0.41	0.25	0.20	0.23	0.28	0.25	0.27
T₁₁	0.51	0.43	0.47	0.30	0.26	0.28	0.35	0.32	0.34
S. Em±	0.02	0.02	0.06	0.03	0.02	0.03	0.02	0.03	0.02
C. D. at 5%	0.05	0.05	0.16	0.10	0.05	0.08	0.07	0.08	0.07
CV (%)	6.02	6.85	6.44	5.68	4.87	5.28	11.56	15.03	13.00

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

The concentration of micronutrients in tomato fruit as influenced by foliar application of fortified distillery spentwash at harvest is presented in Table 58. The concentration of all micronutrients was higher in tomato fruit grown during 2013 compared to 2014.

Significantly higher concentration of Fe, Mn, Zn, Cu, and B was observed in treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (590.3, 200.5, 98.20, 16.0, 11.2 mg kg⁻¹ and 532.5, 182.3, 60.20, 13.50, 10.9 mg kg⁻¹, respectively) compared to all the other treatments during 2013 and 2014. However, lower Fe, Mn, Zn, Cu, and B contents were recorded in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (464.0, 84.2, 68.70, 12.80, 9.30 mg kg⁻¹ and 365.0, 92.0, 30.70, 10.0, 9.3 mg kg⁻¹, respectively) during 2013 and 2014.

The results of pooled analysis of two years (2013 and 2014) data revealed that the concentration of Fe, Mn, Zn, Cu, and B in tomato fruit varied significantly. Higher concentrations of Fe, Mn, Zn, Cu, and B were recorded in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (561.4, 191.4 79.20, 14.75 and 11.1 mg kg⁻¹, respectively) compared to all the other treatments. Lower concentrations of Zn, B, Fe, Mn and Cu (414.5, 88.1 49.70, 11.40 and 9.3 mg kg⁻¹, respectively) were observed in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

4.5.7 Nutrient concentration in tomato haulm (leaves and stem) at harvest

The data on concentration of nitrogen, phosphorus and potassium in tomato haulm varied significantly due to foliar application of fortified distillery spentwash at harvest. The concentration of nitrogen, phosphorus and potassium was higher in tomato haulm grown during 2013 compared to 2014.

During both the years (2013 and 2014), nitrogen, phosphorus and potassium concentration in tomato haulm (Table 59) was significantly higher in T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (1.71, 0.41, 1.98 % and 1.46, 0.33, 1.53 %, respectively) compared to the other treatments. The concentration of NPK was lower in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (1.50, 0.27, 1.69 % and 1.21, 0.17, 1.25 %, respectively).

The pooled analysis of two years data revealed that the concentration of N, P and K in tomato haulm was significantly higher in the treatment T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (1.59, 0.37 and 1.76 %, respectively) and it was on par with T₆ and T₈ (1.56, 0.36, 1.73 and 1.54, 0.34, 1.68 %, respectively). Significantly lower concentration of N, P and K was recorded in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (1.36, 0.22 and 1.47 %, respectively).

Table 58. Effect of foliar application of fortified distillery spentwash on micronutrients content at harvest of tomato fruit grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(mg kg ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	549.2	466.0	507.6	166.2	138.0	152.1	86.50	48.50	67.50	14.80	12.30	13.55	10.5	10.4	10.4
T ₂	534.2	448.0	491.1	151.2	128.0	139.6	82.40	44.40	63.40	14.50	12.00	13.25	10.2	10.2	10.2
T ₃	490.4	403.0	446.7	118.1	102.0	110.1	74.20	36.20	55.20	13.80	11.30	12.55	9.6	9.9	9.7
T ₄	472.4	376.0	424.2	96.3	98.0	97.2	69.50	31.50	50.50	13.10	10.60	11.85	9.4	9.5	9.5
T ₅	464.0	365.0	414.5	84.2	92.0	88.1	68.70	30.70	49.70	12.80	10.00	11.40	9.3	9.3	9.3
T ₆	581.4	508.2	544.8	190.5	174.2	182.4	94.20	56.20	75.20	15.60	13.10	14.35	10.8	10.7	10.7
T ₇	590.3	532.5	561.4	200.5	182.3	191.4	98.20	60.20	79.20	16.00	13.50	14.75	11.2	10.9	11.1
T ₈	562.5	490.0	526.3	181.5	157.3	169.4	91.50	53.50	72.50	15.20	12.70	13.95	10.5	10.5	10.5
T ₉	509.2	418.0	463.6	134.2	115.0	124.6	76.50	38.50	57.50	14.00	11.50	12.75	9.9	10.0	9.9
T ₁₀	481.2	391.0	436.1	107.2	99.0	103.1	71.80	33.80	52.80	13.40	10.90	12.15	9.6	9.6	9.6
T ₁₁	518.7	430.0	474.4	147.1	121.0	134.1	80.40	42.40	61.40	14.20	11.70	12.95	10.1	10.1	10.1
S. Em±	17.38	17.41	16.98	8.70	8.70	8.49	3.11	2.58	2.80	0.63	0.70	0.66	0.35	0.31	0.32
C. D. at 5%	51.28	51.35	48.45	25.68	25.68	24.24	9.19	7.62	8.00	1.87	2.05	1.88	1.03	0.92	0.92
CV (%)	5.76	6.87	6.11	10.52	11.79	10.85	6.64	10.34	7.8	7.66	10.24	8.74	5.97	5.34	5.55

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval
T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 59. Effect of foliar application of fortified distillery spentwash on primary nutrients content in haulm of tomato plant grown during 2013 and 2014.

Treatments	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	1.64	1.39	1.52	0.36	0.28	0.32	1.87	1.41	1.64
T ₂	1.62	1.37	1.50	0.35	0.27	0.31	1.85	1.39	1.62
T ₃	1.56	1.31	1.44	0.31	0.23	0.27	1.79	1.34	1.57
T ₄	1.52	1.27	1.40	0.28	0.20	0.24	1.72	1.28	1.50
T ₅	1.50	1.21	1.36	0.27	0.17	0.22	1.69	1.25	1.47
T ₆	1.68	1.43	1.56	0.40	0.32	0.36	1.95	1.51	1.73
T ₇	1.71	1.46	1.59	0.41	0.33	0.37	1.98	1.53	1.76
T ₈	1.66	1.41	1.54	0.38	0.30	0.34	1.90	1.46	1.68
T ₉	1.58	1.33	1.46	0.32	0.24	0.28	1.80	1.37	1.59
T ₁₀	1.55	1.30	1.43	0.30	0.22	0.26	1.77	1.34	1.56
T ₁₁	1.60	1.35	1.48	0.33	0.25	0.29	1.82	1.38	1.60
S. Em±	0.03	0.03	0.03	0.02	0.02	0.02	0.04	0.04	0.04
C. D. at 5%	0.08	0.09	0.08	0.07	0.05	0.06	0.13	0.13	0.12
CV (%)	2.9	4.0	3.4	12.0	11.8	12.7	4.2	5.6	4.7

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

The concentration of calcium, magnesium and sulphur in tomato haulm varied significantly due to foliar application of fortified distillery spentwash (Table 60).

The concentration of calcium, magnesium and sulphur was higher in tomato crop grown during 2013 as compared to crop grown during 2014. However, significantly higher concentration of calcium, magnesium and sulphur was observed in treatment T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (0.58, 0.37, 0.40 % and 0.52, 0.32, 0.38 %, respectively) during both the years. Whereas lower calcium, magnesium and sulphur content was recorded in T₅ treatment receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (0.30, 0.19, 0.20 % and 0.28, 0.12, 0.14 %, respectively) during 2013 and 2014 respectively

Pooled analysis of two years experimental data showed significantly higher Ca, Mg and S concentration in tomato haulm in the treatment T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (0.55, 0.35 and 0.39 %, respectively) and it was on par with treatment T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (0.53, 0.33 and 0.37 %, respectively) compared to the other treatments. Significantly lower concentration of Ca, Mg and sulphur was recorded in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (0.29, 0.16 and 0.17 %, respectively) during 2013 and 2014.

The concentration of micronutrients in tomato haulm varied significantly due to application of fortified distillery spentwash as foliar spray (Table 61).

The pooled analysis of two years data revealed that the concentrations of Fe, Mn, Zn, Cu, and B in tomato haulm varied significantly. Higher concentration of Fe, Mn, Zn, Cu, and B were recorded in the treatment T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (508.7, 171.4, 84.5, 14.60 and 10.8 mg kg⁻¹, respectively) compared to all the other treatments and it was on par with treatment T₆ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (500.6, 164.2, 83.1, 14.20 and 10.5 mg kg⁻¹, respectively). However, lower concentrations of Fe, Mn, Zn, Cu, and B (380.8, 97.9, 51.7, 10.95 and 9.1 mg kg⁻¹, respectively) were observed in treatment T₅ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

4.5.8 Nutrient uptake by whole tomato crop at harvest

The data pertaining to nitrogen, phosphorus and potassium uptake by tomato crop differed significantly due to foliar application of fortified (SW1 and SW2) distillery spentwash at harvest (Table 62).

Table 60. Effect of foliar application of fortified distillery spentwash on secondary nutrients content in haulm of tomato plant grown during 2013 and 2014.

Treatments	Calcium (%)			Magnesium (%)			Sulphur (%)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	0.51	0.45	0.48	0.30	0.27	0.29	0.35	0.33	0.34
T₂	0.49	0.44	0.47	0.27	0.25	0.26	0.34	0.31	0.33
T₃	0.42	0.37	0.40	0.24	0.19	0.22	0.27	0.24	0.26
T₄	0.38	0.32	0.35	0.21	0.14	0.18	0.22	0.18	0.20
T₅	0.30	0.28	0.29	0.19	0.12	0.16	0.20	0.14	0.17
T₆	0.55	0.50	0.53	0.35	0.30	0.33	0.38	0.36	0.37
T₇	0.58	0.52	0.55	0.37	0.32	0.35	0.40	0.38	0.39
T₈	0.54	0.47	0.51	0.32	0.28	0.30	0.37	0.35	0.36
T₉	0.44	0.40	0.42	0.26	0.21	0.24	0.29	0.27	0.28
T₁₀	0.41	0.34	0.38	0.23	0.16	0.20	0.24	0.21	0.23
T₁₁	0.45	0.41	0.43	0.25	0.22	0.24	0.30	0.28	0.29
S. Em±	0.03	0.02	0.04	0.03	0.02	0.03	0.02	0.02	0.02
C. D. at 5%	0.10	0.06	0.10	0.10	0.05	0.08	0.05	0.05	0.05
CV (%)	12.23	7.90	10.60	22.18	13.48	18.87	9.87	10.87	10.10

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 61. Effect of foliar application of fortified distillery spentwash on micronutrients content in haulm of tomato plant grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(mg kg ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	512.2	429.0	470.6	154.2	143.2	148.7	92.8	63.8	78.3	14.8	12.8	13.80	10.2	9.9	10.0
T₂	498.6	417.0	457.8	139.6	138.6	139.1	89.5	60.5	75.0	14.4	12.4	13.40	10.0	9.7	9.8
T₃	456.1	382.0	419.0	116.5	120.4	118.5	72.4	46.5	59.5	13.5	11.5	12.50	9.5	9.5	9.5
T₄	428.6	358.0	393.3	105.6	102.6	104.1	67.4	42.0	54.7	12.6	10.0	11.30	9.2	9.3	9.2
T₅	416.5	345.0	380.8	100.2	95.6	97.9	62.8	40.5	51.7	12.4	9.5	10.95	9.1	9.2	9.1
T₆	534.1	467.0	500.6	172.1	156.2	164.2	97.6	68.6	83.1	15.2	13.2	14.20	10.6	10.3	10.5
T₇	540.3	477.0	508.7	180.2	162.5	171.4	99.8	69.2	84.5	15.6	13.6	14.60	11.0	10.6	10.8
T₈	521.5	445.3	483.4	163.2	150.2	156.7	94.2	65.2	79.7	15.0	13.0	14.00	10.3	10.1	10.2
T₉	468.5	398.0	433.3	124.2	128.6	126.4	75.6	50.2	62.9	13.8	11.8	12.80	9.6	9.6	9.6
T₁₀	448.6	367.0	407.8	110.2	110.2	110.2	70.6	44.8	57.7	13.0	10.6	11.80	9.4	9.4	9.4
T₁₁	479.5	405.0	442.3	130.2	132.1	131.2	81.6	54.2	67.9	14.1	12.1	13.10	9.8	9.7	9.7
S. Em±	24.11	17.41	31.82	8.70	10.33	9.46	3.11	2.77	2.91	0.63	0.69	0.65	0.37	0.26	0.32
C. D. at 5%	71.14	51.35	90.82	25.68	30.47	26.99	9.19	8.17	8.29	1.87	2.03	1.85	1.10	0.77	0.91
CV (%)	8.66	7.39	12.38	11.08	13.66	12.27	6.56	8.72	7.34	7.80	10.04	8.71	6.55	4.65	5.60

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 62. Effect of foliar application of fortified distillery spentwash on primary nutrients uptake at harvest by tomato crop grown during 2013 and 2014.

Treatments	Nitrogen (kg ha ⁻¹)			Phosphorus (kg ha ⁻¹)			Potassium (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	174.1	139.5	156.8	31.6	22.2	26.9	198.4	164.0	181.2
T ₂	177.7	142.3	160.0	31.0	21.4	26.2	201.7	167.1	184.4
T ₃	177.5	140.1	158.8	28.2	18.3	23.2	196.6	161.5	179.1
T ₄	170.3	135.5	152.9	23.7	14.4	19.1	188.5	157.2	172.9
T ₅	173.7	136.9	155.3	23.4	13.4	18.4	190.9	160.0	175.5
T ₆	217.5	175.1	196.3	40.7	29.1	34.9	249.8	209.9	229.9
T ₇	219.8	176.5	198.2	42.6	30.1	36.4	253.4	211.6	232.5
T ₈	214.9	173.4	194.1	39.2	27.9	33.6	245.5	207.0	226.2
T ₉	201.1	160.7	180.9	32.3	21.5	26.9	227.8	191.5	209.7
T ₁₀	203.4	163.7	183.5	29.5	18.7	24.1	228.7	194.4	211.5
T ₁₁	213.8	171.8	192.8	35.6	24.2	29.9	241.8	204.0	222.9
S. Em±	8.18	7.03	7.45	1.32	0.96	1.13	9.23	8.53	8.68
C. D. at 5%	24.13	20.72	21.26	3.88	2.83	3.21	27.22	25.18	24.77
CV (%)	7.27	7.80	7.44	7.01	7.56	7.16	7.26	8.02	7.43

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

The nitrogen, phosphorus and potassium uptake by tomato crop was higher during 2013 than during 2014. During both the years, significantly higher nitrogen, phosphorus and potassium uptake by tomato crop was recorded in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (219.8, 42.6, 253.4 and 176.5, 30.1, 211.6 kg ha⁻¹, respectively) compared to treatment T₅ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval. (173.7, 23.4, 190.9 and 136.9, 13.4, 160.0 kg ha⁻¹, respectively).

The pooled analysis of data of two years (2013 and 2014) indicated that significantly higher nitrogen, phosphorus and potassium uptake (198.2, 36.4 and 232.5 kg ha⁻¹, respectively) by tomato crop was noticed in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval. However, significantly lower nitrogen, phosphorus and potassium uptake by tomato crop was noticed in treatment T₅ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval. (155.3, 18.4 and 175.5 kg ha⁻¹, respectively).

The uptake of calcium, magnesium and sulphur by tomato crop differed significantly due to foliar application of fortified spentwash (Table 63).

During 2013, the uptake of Ca, Mg and S by tomato crop was significantly lower (32.5, 17.9 and 19.9 kg ha⁻¹, respectively) in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval and it increased to 59.4, 38.6, 44.7 kg ha⁻¹ respectively in treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval. Similar trend was observed during 2014.

The results of pooled analysis revealed that 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) recorded significantly higher uptake of Ca, Mg and S (55.1, 35.4 and 41.9 kg ha⁻¹, respectively) by tomato crop compared to all the other treatments. However, significantly lower uptake of Ca, Mg and S by tomato crop (28.9, 14.8 and 17.5 kg ha⁻¹, respectively) was observed in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval

The results on uptake of Fe, Mn, Zn, Cu and B by tomato crop varied significantly due to foliar application of fortified distillery spentwash at harvest (Table 64). The uptake of micronutrients by tomato crop was higher during 2013 compared to 2014.

During 2013, higher uptake of Fe, Mn, Zn, Cu and B were recorded due to 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇) (5674, 1915, 981.2, 157.4 and 110.7 g ha⁻¹) compared to all the other treatments. Similar trend was observed during 2014.

Table 63. Effect of foliar application of fortified distillery spentwash on secondary nutrients uptake at harvest by tomato crop grown during 2013 and 2014.

Treatments	Calcium (kg ha ⁻¹)			Magnesium (kg ha ⁻¹)			Sulphur (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	43.4	37.1	40.3	26.6	22.9	24.8	31.7	28.6	30.2
T ₂	43.3	36.8	40.0	25.8	21.9	23.8	30.7	27.8	29.2
T ₃	37.6	32.0	34.8	22.2	17.2	19.7	25.3	22.4	23.9
T ₄	33.7	27.4	30.6	19.1	13.5	16.3	20.4	16.7	18.6
T ₅	32.5	25.4	28.9	17.9	11.7	14.8	19.9	15.1	17.5
T ₆	56.7	48.8	52.8	36.4	30.4	33.4	41.9	38.0	39.9
T ₇	59.4	50.7	55.1	38.6	32.3	35.4	44.7	39.2	41.9
T ₈	54.3	47.3	50.8	34.6	28.6	31.6	40.8	36.5	38.7
T ₉	44.1	38.2	41.1	26.6	21.9	24.3	30.8	28.8	29.8
T ₁₀	40.8	34.9	37.8	23.5	17.9	20.7	25.8	22.6	24.2
T ₁₁	48.9	41.1	45.0	28.3	24.0	26.2	33.3	31.2	32.2
S. Em±	1.81	1.66	1.70	1.12	0.99	1.03	1.31	1.27	1.26
C. D. at 5%	5.35	4.91	4.86	3.29	2.91	2.94	3.87	3.75	3.60
CV (%)	6.99	7.55	7.09	7.10	7.77	7.24	7.24	7.88	7.37

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 64. Effect of foliar application of fortified distillery spentwash on micronutrients uptake at harvest by tomato crop grown during 2013 and 2014.

Treatments	Iron			Manganese			Zinc			Copper			Boron		
	(g ha ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	4398	3579	3989	1328	1109	1218	732.8	430.6	581.7	121.8	99.0	110.4	85.3	80.7	83.0
T ₂	4382	3547	3965	1235	1071	1153	716.8	408.3	562.6	121.8	98.7	110.2	85.3	81.5	83.4
T ₃	4106	3246	3676	1006	884	945	629.8	323.5	476.7	117.2	93.1	105.2	82.1	79.9	81.0
T ₄	3791	2982	3386	820	799	810	569.1	278.5	423.8	107.0	83.8	95.4	77.4	75.8	76.6
T ₅	3805	2958	3381	750	765	757	566.0	274.1	420.0	107.1	81.1	94.1	78.1	76.0	77.0
T ₆	5565	4696	5131	1813	1598	1705	940.5	573.0	756.8	152.4	124.7	138.5	105.4	100.2	102.8
T ₇	5674	4878	5276	1915	1667	1791	981.2	602.3	791.7	157.4	128.7	143.0	110.7	102.5	106.6
T ₈	5383	4527	4955	1720	1476	1598	907.6	545.8	726.7	148.6	121.9	135.2	102.5	99.1	100.8
T ₉	4712	3797	4254	1244	1097	1171	723.7	387.0	555.3	132.3	106.8	119.6	92.8	91.4	92.1
T ₁₀	4534	3638	4086	1038	965	1002	686.5	348.0	517.2	127.6	102.4	115.0	91.5	90.5	91.0
T ₁₁	5039	4095	4567	1411	1204	1308	803.7	444.7	624.2	141.0	114.5	127.8	99.5	96.8	98.1
S. Em±	185.32	165.45	171.73	53.81	49.67	50.63	29.45	17.44	23.66	5.10	4.49	4.69	3.58	3.81	3.61
C. D. at 5%	546.68	488.06	490.12	158.74	146.54	144.49	86.86	51.44	67.54	15.03	13.23	13.40	10.55	11.23	10.31
CV (%)	6.87	7.52	7.01	7.18	7.49	7.17	6.79	7.20	7.00	6.77	7.40	6.91	6.74	7.44	6.93

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Pooled analysis of two years experimental data showed significantly higher uptake of Fe, Mn, Zn, Cu and B by tomato crop in the treatment T₇ that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (5276, 1791, 791.7, 143.0, and 106.6 g ha⁻¹, respectively). Lower uptake of Fe, Mn, Zn, Cu and B by tomato crop (3381, 757, 420.0, 94.1 and 77.0 g ha⁻¹, respectively) was observed in the treatment T₅ which received 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.

Significantly higher nutrient concentration in tomato fruit, haulm and nutrient uptake was observed in respect of cations (Ca, Mg and K) and anions (N, P and S) by the tomato crop at harvest during 2013 and 2014 with the foliar application of fortified distillery spentwash. Fortified distillery spentwash (SW 2) has higher amounts of nitrogen, zinc, boron and other nutrients, which are soluble and can be easily absorbed by plants when sprayed. Significantly higher concentration and uptake of all the nutrients was recorded in treatment T₇ which received 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval. This could be due to the more absorption of plant nutrients present in spentwash by plants. Chandrāju *et al.* (2012) reported there is negative impact of heavy metals like lead, cadmium and nickel on the leaves of V-1 mulberry plants.

The increased nutrient concentration and dry matter accumulation in plant may be attributed to greater accumulation of photosynthates by vegetative parts in the plants receiving nutrients through foliar application. Similar results were also reported by Thiyageshwari and Ramanathan (2001). The foliar application of micronutrients favoured the accumulation of even macronutrients due to their role in activation of enzymes, involved in metabolic processes. Increased nutrient uptake and yield may be attributed to the enhanced photosynthetic activity and increased production and accumulation of carbohydrates. The SW 2 being fortified with nitrogen, zinc and boron when used for foliar spray enhanced the uptake of all the macro and micronutrients in tomato plant, most of the individual micronutrient treatments also showed significant improvement in the uptake of different nutrients in tomato plant compared to plant receiving water spray and SW 1 (fortified with only nitrogen). The above findings are in conformity with the findings of Patnaik *et al.* (2001) and Selvaraj *et al.* (2002). However, significantly lower nutrient concentration in fruits and haulm and nutrient uptake by plant was noticed in the treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval. Foliar application of nutrient solutions causes salt concentrations on a leaf surface to be higher than those of soil solutions. Increased tolerance of the epidermis to high spray solution concentrations is caused by the presence of the wax layer and the cuticular membrane. Since most mineral nutrients passively diffuse into the epidermal cells, absorption depends on their concentrations on the leaf surface. However, elevated nutrient concentrations cause leaf injury leading to the reduction in nutrient absorption. Maximum concentrations of particular mineral nutrients in a spray solution depend on plant species, plant development stage, plant nutritional status, plant healthiness and weather conditions (Wittwer and Teubner, 1959).

4.5.9 Changes in soil properties after harvest of tomato crop

Chemical properties

The changes in pH, electrical conductivity and organic carbon content of soil after the harvest of tomato crop due to foliar application of fortified distillery spentwash (SW 1 and SW 2) are presented in Table 65. The available nutrient status of soil after harvest of tomato crop was higher in 2014 compared to 2013. At the time of foliar application of fortified distillery spentwash, plants absorb only 30-40% of spray solution and the remaining 60-70% remaining solution drop on surface of soil and therefore the concentration of nutrients may enhance appreciably.

There was significant variation in the pH, electrical conductivity and organic carbon content of soil due to foliar application of SW 1 and SW 2. However, significantly higher pH and electrical conductivity of soil was observed in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (7.98, 0.31 dSm⁻¹ and 7.98, 0.45 dSm⁻¹ during 2013 and 2014, respectively) compared to all the other treatments. Significantly lower pH and EC were observed in the treatment T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (7.44, 0.19 dSm⁻¹ and 7.51, 0.31 dSm⁻¹). There was slight increase in pH of soil due to foliar application distillery spentwash compared to initial values. Sweeney and Granetz (1991) reported that the addition of distillery effluent regardless of rate raised the soil pH, owing to increase in soil K, Ca, Mg, and Na levels. Mattiazo and Ada Gloria (1985) found that the organic matter oxidation brought about by microbial activity was responsible for increased pH of the soil treated with distillery effluent. The EC of the post harvest soil was increased compared to the initial value due to the application of undiluted treated distillery spentwash (T₂). The spentwash contains more amount of soluble salt which get accumulated in the soil. The EC of soil of the treated distillery spentwash was well within the safer limit. The findings of the present study are supported by the work of Selvakumar (2006). The increase in organic carbon content of soil was higher during 2014 than 2013. This might be due to the organic load in the distillery spentwash, addition of crop residues and root biomass. The results are in line with Gurumurthy (1996). Significantly higher organic carbon content of soil was recorded in treatment T₅ that received 70% RDN through fertilizers+ 30% RDN through 2 sprays of fortified SW 1 at 10 days interval (7.30 and 8.30 g kg⁻¹) during 2013 and 2014 respectively. The lower organic carbon content (5.40 and 5.90 g kg⁻¹) was recorded in the treatment T₁₁ which received RDF with water spray (6 times).

The pooled analysis of two years data showed significantly higher pH and salt content of soil in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (7.98 and 0.38 dSm⁻¹ during 2013 and 2014, respectively) and higher organic carbon content of soil was noticed in the treatment T₁ which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval compared to all the other treatments. However, significantly lower pH, salt content and organic carbon content of soil were recorded in treatments T₆ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval and T₁ receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval.

Table 65. Effect of foliar application of fortified distillery spentwash on pH, electrical conductivity and organic carbon content of soil after the harvest of tomato crop grown during 2013 and 2014.

Treatments	pH (1:2.5)			EC (dSm ⁻¹)			Organic carbon (g kg ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	7.85	7.90	7.87	0.25	0.38	0.32	5.30	7.20	0.62
T ₂	7.87	7.92	7.89	0.26	0.39	0.32	6.20	7.40	6.80
T ₃	7.93	7.93	7.93	0.29	0.41	0.35	6.70	7.80	7.30
T ₄	7.94	7.95	7.94	0.30	0.43	0.36	7.10	8.10	7.60
T ₅	7.98	7.98	7.98	0.31	0.45	0.38	7.30	8.30	7.80
T ₆	7.44	7.51	7.48	0.19	0.31	0.25	5.20	6.20	5.70
T ₇	7.51	7.52	7.52	0.22	0.35	0.28	5.60	6.50	6.10
T ₈	7.53	7.55	7.54	0.23	0.35	0.29	6.10	7.90	7.00
T ₉	7.58	7.58	7.58	0.23	0.37	0.30	6.40	7.20	6.80
T ₁₀	7.62	7.59	7.61	0.24	0.36	0.30	6.80	7.60	7.20
T ₁₁	7.80	7.77	7.79	0.17	0.19	0.18	5.40	5.90	5.70
S. Em±	0.06	0.10	0.08	0.03	0.04	0.03	0.04	0.05	0.04
C. D. at 5%	0.17	0.28	0.22	0.08	0.12	0.10	0.12	0.14	0.13
CV (%)	1.29	2.13	1.74	19.25	19.16	19.37	11.63	11.61	12.97
Initial value	7.55			0.15			4.20		

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

The data pertaining to changes in available nitrogen, phosphorus and potassium content of soil after the harvest of tomato crop due to foliar application of fortified distillery spentwash are presented in Table 66.

The available nitrogen, phosphorus and potassium contents of soil were higher in most of the treatments during 2014 compared to 2013.

After the harvest of 2013 season crop, significantly higher available N content (262.9 kg ha^{-1}) of soil was observed in treatment T_{11} receiving RDF with water spray and lower available N (209.9 kg ha^{-1}) was observed in the treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval. However, significantly higher available phosphorus and potassium content of soil was noticed in the treatment T_5 which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (30.6 and 395.4 kg ha^{-1}). This may be because of lower nutrients uptake by crop which resulted in lower yield and lower available phosphorus and potassium content (25.1 and 326.5 kg ha^{-1}) was noticed in the treatment T_6 receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval. Similar trend was observed after the harvest of crop during 2014. The available nitrogen, phosphorus and potassium content in soil of different treatments at final picking stage was significantly influenced by foliar application of SW 2. The lower available nitrogen, phosphorus and potassium content might be due to higher uptake of nutrients by plants and its further translocation to various plant parts including fruit. Further, FYM improved the physico-chemical properties in the root environment that has resulted in increased vegetative growth, yield and yield component there by decreasing available NPK content in soil.

Pooled analysis of two year data showed significantly higher available nitrogen content (273.1 kg ha^{-1}) of soil in treatment T_{11} receiving RDF with water spray (6 times) compared to all the other treatments and it was on par with treatment T_1 which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval (266.9 kg ha^{-1}) and lower available nitrogen content (216.2 kg ha^{-1}) was observed in the treatment T_6 receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval. Significantly higher available phosphorus and potassium content was noticed in the treatment T_5 which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (32.1 and 409.3 kg ha^{-1}). However, significantly lower available phosphorus and potassium content of soil was observed in treatment T_6 which received 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (25.5 and 339.5 kg ha^{-1} , respectively during 2013 and 2014).

The available nitrogen, phosphorous and potassium contents of the soil has increased due to foliar application of distillery effluent. The contribution of nitrogen from distillery effluent and enhanced microbial activity upon addition of organic matter might have increased the available nitrogen content of the soil (Subash Chandra Bose *et al*, 2002).

Table 66. Effect of foliar application of fortified distillery spentwash on available N, P and K content of soil after the harvest of tomato crop grown during 2013 and 2014.

Treatments	Available-N (kg ha ⁻¹)			Available-P ₂ O ₅ (kg ha ⁻¹)			Available-K ₂ O (kg ha ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	258.5	275.3	266.9	26.1	27.6	26.9	338.7	371.3	355.0
T ₂	255.6	271.1	263.4	26.7	28.3	27.5	359.8	388.6	374.2
T ₃	238.4	262.0	250.2	27.5	31.1	29.3	369.3	407.4	388.3
T ₄	230.2	256.6	243.4	29.3	32.1	30.7	387.5	415.8	401.7
T ₅	228.0	253.3	240.6	30.6	33.6	32.1	395.4	423.3	409.3
T ₆	250.2	264.5	257.4	25.1	25.8	25.5	326.5	352.5	339.5
T ₇	246.2	256.8	251.5	25.9	26.7	26.3	345.6	365.6	355.6
T ₈	224.6	243.3	234.0	27.2	28.4	27.8	352.5	386.4	369.5
T ₉	216.6	235.4	226.0	28.8	30.3	29.6	376.5	402.5	389.5
T ₁₀	209.9	222.6	216.2	30.1	31.1	30.6	381.7	418.2	400.0
T ₁₁	262.9	283.4	273.1	29.5	31.4	30.5	378.4	394.5	386.5
S. Em±	10.50	8.18	9.31	1.04	1.55	1.47	11.98	11.29	11.42
C. D. at 5%	30.97	24.13	26.56	3.05	4.58	4.20	35.34	33.31	32.59
CV (%)	7.63	5.52	6.51	6.43	9.06	8.85	5.69	4.97	5.22
Initial value	223.2 (kg ha⁻¹)			30.5 (kg ha⁻¹)			360.5 (kg ha⁻¹)		

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Application of nitrogen through fertilizers also increased the available nitrogen status of the soil. In addition to the phosphorus contributed by the effluent, HCO_3 content of the distillery effluent and organic acids produced during the decomposition of the distillery effluent would have helped to solubilize the native soil phosphorous (Rajukkannu *et al*, 1996). Somashekar *et al*, (1984) opined that the mineralization of organic material as well as the nutrients present in the effluents are responsible for the increase in the availability of plant nutrients. Bertranou *et al*. (1987) reported that the available potassium was increased by four to five times due to the fact that potassium is the major component of the spentwash and will be supplied in large quantities.

Data on the effect of application fortified (SW 1 and SW 2) distillery spentwash on exchangeable-calcium, magnesium, sodium and available sulphur content of soil after the harvest of tomato crop are presented in Table 67.

The exchangeable-calcium, magnesium, sodium and available sulphur contents of soil were higher in most of the treatments during 2014 compared to 2013. Significantly higher exchangeable calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T_5 receiving : 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (8.6, 4.6, 0.91 c mol (p+) kg^{-1} and 22.7 mg kg^{-1} , respectively) compared to all the other treatments during 2013. Similar trend was followed in 2014. Increased Ca+Mg content in the soil was due to the presence of 1452 mg L^{-1} of Ca and 790 mg L^{-1} of Mg in treated spentwash spentwash that was added to the soils through foliar application in different quantities which helped in better replacement of exchangeable sodium by Ca ions. The higher sodium content was observed in the treatments receiving foliar application of SW 1. This may be attributed to higher content of sodium containing soluble salts in the distillery spentwash. Since the crop uptake of sodium might be lower there was slight build up of the sodium in soil which may affect crop growth and development. These results are in line with the findings of Bhagyalakshmi (2009) and Senthilraja (2010). However, lower calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T_6 receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (6.50, 2.90, 0.57 c mol (p+) kg^{-1} and 14.4 mg kg^{-1} , respectively) during 2013. This is because of higher uptake of these nutrient elements by the crop.

The pooled analysis of data of two years (2013 and 2014) showed that significantly higher exchangeable of calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T_5 which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (8.90, 4.90, 1.05 c mol (p+) kg^{-1} and 24.1 mg kg^{-1} , respectively) compared to all the other treatments during 2013. Similar trend of results was observed in 2014. However, significantly lower calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T_6 receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (6.8, 3.1, 0.64 c mol (p+) kg^{-1} and 15.6 mg kg^{-1} , respectively).

Table 67. Effect of foliar application of fortified distillery spentwash on exchangeable Ca, Mg and available S content of soil after the harvest of tomato crop grown during 2013 and 2014

Treatments	Exch. Ca (c mol (p+) kg ⁻¹)			Exch. Mg (c mol (p+) kg ⁻¹)			Exch. Na (c mol (p+) kg ⁻¹)			Avail-S (mg kg ⁻¹)		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	7.1	7.4	7.3	3.1	3.8	3.4	0.72	0.87	0.80	15.2	18.4	16.8
T₂	7.5	7.9	7.7	3.7	4.2	4.0	0.76	0.98	0.87	18.2	21.3	19.8
T₃	7.9	8.5	8.2	4.1	4.5	4.3	0.82	1.06	0.94	19.4	22.1	20.8
T₄	8.1	8.7	8.4	4.3	4.7	4.5	0.88	1.09	0.98	21.3	24.1	22.7
T₅	8.6	9.2	8.9	4.6	5.2	4.9	0.91	1.18	1.05	22.7	25.4	24.1
T₆	6.5	7.1	6.8	2.9	3.2	3.1	0.57	0.71	0.64	14.4	16.8	15.6
T₇	6.9	7.4	7.2	3.1	3.6	3.4	0.61	0.75	0.68	15.7	18.1	16.9
T₈	7.2	7.8	7.5	3.3	3.8	3.6	0.65	0.75	0.70	16.4	19.2	17.8
T₉	7.5	8.2	7.9	3.8	4.3	4.1	0.67	0.79	0.73	20.5	22.1	21.3
T₁₀	7.9	8.6	8.3	4.0	4.7	4.4	0.75	0.84	0.80	21.6	23.8	22.7
T₁₁	7.3	7.8	7.6	3.9	4.3	4.1	0.83	0.90	0.87	19.2	20.4	19.8
S. Em±	0.27	0.36	0.31	0.16	0.24	0.20	0.07	0.05	0.06	0.54	0.60	0.58
C. D. at 5%	0.79	1.06	0.89	0.46	0.70	0.56	0.19	0.15	0.16	1.60	1.77	1.65
CV (%)	6.2	7.7	6.9	7.3	9.7	8.6	15.3	9.9	12.6	5.1	4.9	5.1
Initial value	7.5 (c mol (p+) kg⁻¹)			3.2 (c mol (p+) kg⁻¹)			0.44 (c mol (p+) kg⁻¹)			18.6 (mg kg⁻¹)		

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval

T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Table 68. Effect of foliar application of fortified distillery spentwash on available micronutrients content of soil after the harvest of tomato crop grown during 2013 and 2014.

Treatments	DTPA-Fe			DTPA- Mn			DTPA- Zn			DTPA-Cu			Hot water-B		
	(mg kg ⁻¹)														
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	10.9	16.1	13.5	5.08	5.06	5.07	1.60	1.86	1.73	1.24	1.35	1.30	0.44	0.52	0.48
T ₂	11.5	17.7	14.6	4.89	5.21	5.05	1.63	1.98	1.81	1.27	1.44	1.36	0.31	0.37	0.34
T ₃	12.1	18.2	15.2	5.04	5.53	5.29	1.75	2.05	1.90	1.32	1.56	1.44	0.35	0.43	0.39
T ₄	12.5	19.1	15.8	5.14	6.08	5.61	2.01	2.18	2.10	1.41	1.67	1.54	0.42	0.58	0.50
T ₅	13.5	19.7	16.6	5.41	6.14	5.78	2.29	2.42	2.36	1.48	1.70	1.59	0.51	0.60	0.56
T ₆	11.8	15.6	13.7	4.84	5.10	4.97	2.62	2.87	2.74	1.23	1.41	1.32	0.29	0.38	0.34
T ₇	12.1	16.4	14.3	4.95	5.57	5.26	2.71	2.94	2.83	1.33	1.54	1.44	0.38	0.42	0.40
T ₈	12.6	17.3	15.0	5.24	5.98	5.61	2.80	3.02	2.91	1.42	1.61	1.52	0.45	0.55	0.50
T ₉	13.2	19.3	16.3	5.38	6.05	5.71	2.84	3.10	2.97	1.46	1.65	1.56	0.49	0.59	0.54
T ₁₀	13.8	20.1	16.9	5.52	6.23	5.88	2.91	3.18	3.04	1.53	1.76	1.65	0.52	0.63	0.57
T ₁₁	11.9	14.3	13.1	4.72	5.01	4.87	1.31	1.58	1.44	1.06	1.15	1.10	0.26	0.32	0.29
S. Em±	0.55	1.20	0.91	0.10	0.19	0.15	0.18	0.24	0.22	0.08	0.04	0.07	0.03	0.01	0.02
C. D. at 5%	1.63	3.54	2.61	0.29	0.55	0.42	0.54	0.72	0.62	0.24	0.13	0.19	0.09	0.04	0.07
CV (%)	7.73	11.81	10.6	3.39	5.72	4.73	14.16	17.13	16.0	10.31	5.07	7.92	12.96	4.88	9.00
Initial value	7.64 (mg kg⁻¹)			4.98 (mg kg⁻¹)			1.04 (mg kg⁻¹)			0.64 (mg kg⁻¹)			0.28 (mg kg⁻¹)		

Legend:

T₁: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 1 at 30 days interval
T₂: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 1 at 20 days interval
T₃: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 1 at 15 days interval
T₄: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 1 at 12 days interval
T₅: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval
T₆: 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval
T₇: 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval
T₈: 80% RDN through fertilizers+ 20% RDN through 4 sprays of fortified SW 2 at 15 days interval
T₉: 75% RDN through fertilizers+ 25% RDN through 5 sprays of fortified SW 2 at 12 days interval
T₁₀: 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval
T₁₁: RDF with water sprays (6 times)

Note: RDF- 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹

Data pertaining to the effect of foliar application of fortified distillery spentwash on DTPA extractable micronutrients and available boron content of soil after the harvest of tomato crop are presented in Table 68.

Pooled analysis of data of two years (2013 and 2014) revealed that higher DTPA extractable iron, manganese, zinc, copper and available boron content of soil were observed in the treatment T₁₀ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval (16.9, 1.65, 3.04, 5.88 and 0.57 mg kg⁻¹, respectively) compared to all the other treatments. Foliar application of SW 2 (fortified with nitrogen, zinc and boron). Similar trend of results was observed in 2014 also.

However, lower DTPA extractable iron, manganese, zinc, copper and available boron content of soil were observed in treatment T₁₁ receiving RDF water spray (13.1, 4.87, 1.44, 1.10 and 0.29 mg kg⁻¹, respectively) during 2013. This might be due to higher uptake of micronutrients by the crop because of addition of organic manures and due to synergistic interaction between sulphur and available micronutrients in soil. Higher availability of micro nutrients after the harvest of crop may be attributed to the organic matter added during the crop growth as root exudates, crop residues and applied FYM (Sharma and Gupta, 2001).

4.6 Conclusion

The distillery spentwash, a waste water generated by distilleries, can be utilized as a nutrient rich resource for enhancing the growth, yield, quality of tomato crop. Also, the enormous quantities of plant nutrients present in spentwash offers an excellent opportunity to use it as a liquid fertilizer along with water and fortified with nutrients (nitrogen, zinc and boron), thus enabling the farmers to save on fertilizers and at the same time achieve higher yield of crops. Based on the results of field trials, it can be concluded that tomato crop performed well due to foliar application of 1:5 diluted/fortified distillery spentwash. The spentwash has dissolved nutrients which make it a valuable resource and foliar application of distillery spentwash also increases the available nutrients status in soil.

4.7 Future line of work

- There is a need to work out appropriate dilution of spentwash for foliar application in different crops/soils with varying nutrients concentration.
- Long term impact of foliar application of diluted/fortified distillery spentwash on soil quality and yield of different crops needs to be studied critically.
- In depth study is to be carried out on quality parameters of crops over continuous foliar application of diluted/fortified distillery spentwash.

V SUMMARY

The present investigations “Studies on fortification of distillery spentwash for foliar application and its effect on soil properties, growth and yield of tomato” was carried out during 2013-14. This included a) Characterisation of primary treated distillery spentwash b) laboratory experiment at GKVK to study the growth regulating properties of distillery spentwash through bioassay c) pot experiment under green house condition at GKVK to identify the best dilution and d) two field experiments were conducted at Gurudevarahalli, Maddur Taluk, Mandya. The first experiment was conducted to study the effect of distillery spentwash of different dilution as a foliar spray on growth and yield of tomato and on soil properties. The second field experiment was conducted to determine the optimum proportion of nutrients for preparation of fortified spentwash and to study the effect of fortified spentwash on growth and yield of tomato and on soil properties. Brief summary of this investigation is presented below.

Characteristics of distillery spentwash

The distillery spentwash from the M/s Sri Chamundeshwari Sugars Ltd., K. M. Doddi, Mandya district were analyzed for important physical and chemical properties and the results are summarized below.

- Analysis of primary treated distillery spentwash the samples collected at bimonthly interval revealed that the distillery spentwash was neutral in reaction (pH 7.32) and electrical conductivity of the effluent was high (28.5 dS m⁻¹).
- The total N, P and K contents of distillery spentwash samples were 0.12, 0.04 and 1.02 % respectively.
- The BOD and COD of the distillery spentwash sample were 5988 and 33568 mg L⁻¹, respectively.
- The distillery spentwash contained some substantial concentration of Ca, Mg and Na (1452, 790 and 645 mg L⁻¹, respectively).
- The TDS, TSS and TS content were 4.68, 1.68 and 6.36 %, respectively.
- The chlorides content of the distillery spentwash was high (4783 mg L⁻¹) and the sulphate content was 672 mg L⁻¹.
- The distillery spentwash samples contain some quantities of micronutrients like Fe, Mn, Zn, Cu and B (22.5, 4.28, 6.52, 2.32 and 1.08 mg L⁻¹, respectively).
- The distillery spentwash samples did not contain any heavy metals or oil and grease.

Laboratory experiment

- In the laboratory experiment, 100 percent seed germination and speed of germination of cowpea and sunflower was noticed in the treatments which received diluted distillery spentwash from 1:5 dilutions to 1:10 dilution and also water spray. No germination or very poor germination percent and speed of germination of cowpea and sunflower were observed in the undiluted distillery spentwash on 2nd, 3rd, 4th and 5th day after sowing.
- In tomato crop, the highest seed germination and speed of germination was observed from 1:8 dilution to 1:10 dilution (spentwash:water) and poor or no germination was noticed in rest of the treatments at 2nd, 3rd, 4th and 5th days after sowing.
- In cowpea and sunflower crops, higher shoot length (8.61 cm and 6.66 cm), root length (3.40 cm and 3.94 cm) and vigour index values (1201 and 1061) were recorded in 1:5 dilution which was on par with 1:6 dilution (8.40 cm & 6.48 cm), (3.24 cm and 3.60 cm) and (1164 and 1008) respectively and lower values were observed in the undiluted distillery spentwash.
- In tomato crop, higher shoot length (7.53 cm) root length (4.54 cm) and vigour index (1208%) were recorded in 1:8 dilution. The values were lower in rest of the treatments.

Green House Experiment

- In the green house experiment higher plant height (21.2cm), number of leaves per plant (12.0) and SPAD meter reading (12.5) of cowpea was recorded in the treatment which received 1:5 dilution of distillery spentwash at weekly intervals and lower plant height (13.5 cm), lesser number of leaves per plant (7.0) and SPAD meter reading (8.0) were noticed in the foliar application of undiluted distillery spentwash.
- In sunflower, significantly higher plant height (52.9 cm), number of leaves per plant (10.0) and higher SPAD meter reading (11.3) were recorded in the treatment which received 1:4 and 1:3 dilution of distillery spentwash at weekly intervals and lower plant height (27.2 cm), less number of leaves per plant (6.0) and SPAD meter reading (6.3) were noticed due to foliar application of undiluted distillery spentwash.
- Significantly higher plant height (27cm), number of leaves per plant (7.0) and higher SPAD meter reading (21.6) of tomato were recorded in the treatment which received 1:5 dilution of distillery spentwash at weekly intervals and significantly lower plant height (15.9 cm) lesser number of leaves per plant (4.3) and higher SPAD meter reading (10.6) were noticed due to foliar application of undiluted distillery spentwash.

Field experiment-I: Effect of different dilution of distillery spentwash as a foliar spray on growth and yield of tomato and on soil properties

- All the growth parameters at different growth stages and yield parameters at harvest of tomato crop was significantly influenced by the foliar application of diluted distillery spentwash at different intervals.
- All the growth parameters at different growth stages and yield parameters at harvest of tomato-tomato cropping sequence were higher during 2013 compared to 2014.
- At 60 DAT, significantly higher plant height, number of branches per plant and SPAD meter reading were observed in treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilutions during 2013 and 2014. Pooled analysis of data indicated that treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilutions (110.2 cm, 11.9 and 22.9 respectively) recorded significantly higher plant height, number of branches per plant and SPAD meter reading.
- Significantly lower plant height, number of branches per plant and SPAD meter reading were observed in treatment T₁₃ receiving 100% RDF + water spray (81.4 cm, 8.2 and 11.0 respectively) and T₁ which received 100% RDF + 4 sprays of undiluted distillery spentwash during 2013 and 2014 (84.0 cm, 8.7 and 11.7 respectively). Similar trend was observed at 90 DAT and at harvest.
- The treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher 10 fruit weight at different picking stages of tomato compared to foliar application of undiluted distillery spentwash and water spray during 2013 and 2014.
- Significantly higher fruit yield ha⁻¹ during 2013 was recorded in the treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (84.4 t ha⁻¹) and lower fruit yield was observed in T₁₃ which received 100% RDF + water sprays (57.4 t ha⁻¹) and treatment T₁ which received 100% RDF + 4 sprays of undiluted distillery spentwash. There was decrease in fruit yield during 2014 compared to 2013.
- Treatment T₁₂ which received 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher TSS value(6.1^oBrix), ascorbic acid content (56.7 mg 100⁻¹ g) and lycopene content (14.5 mg 100⁻¹ g) of tomato. Lower TSS value (4.6 ^oBrix), ascorbic acid content (44.2 mg 100⁻¹ g) and lycopene content (8.0 mg 100⁻¹ g) of tomato were observed in treatment T₁₃ which received water spray during 2013. Similar trend was recorded in the 2014.
- The treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly higher concentration of nitrogen, phosphorus and potassium in tomato fruit and haulm at harvest (2.34, 0.31, 2.89 % and 1.52, 0.32, 1.71 % respectively) during 2013. Similar trend was observed in the 2014.
- Significantly higher concentrations of Fe, Mn, Zn, Cu and B in tomato fruit and tomato haulm were observed in treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (538.3, 199.5, 61.3, 14.3, 10.8 mg kg⁻¹ and 471.2,

169.3, 70.2, 13.7 10.5 mg kg⁻¹, respectively) compared to all the other treatments during 2013. Similar trend was observed in the 2014.

- Significantly lower concentrations of Fe, Mn, Zn, Cu and B in tomato fruit and tomato haulm were observed in treatment T₁₃ receiving 100% RDF + water spray (405.3, 102.3, 37.3, 10.5, 8.64 mg kg⁻¹ and 318.2, 98.2, 27.6, 11.3, 8.4 mg kg⁻¹, respectively) compared to all the other treatments during 2013. Similar trend was observed in 2014.
- Significantly higher uptake of nitrogen, phosphorus and potassium by tomato plant (fruit and haulm) at harvest was recorded in treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (216.5, 32.9, 261.4 and 165.3, 25.8, 202.7 kg ha⁻¹, respectively) compared to treatment T₁₃ which received only water spray (133.7, 13.2, 152.4 and 103.3, 9.3, 118.1 kg ha⁻¹, respectively) during 2013 and 2014.
- Higher uptake of calcium, magnesium and sulphur by tomato plant at harvest was recorded in treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (49.7, 30.8, 42.0 kg ha⁻¹, respectively) and lower uptake of calcium, magnesium and sulphur by tomato plant at harvest was recorded in treatment T₁₃ receiving 100% RDF + water spray (18.3, 8.8 and 15.6 kg ha⁻¹ respectively) during 2013 and 2014, respectively).
- Higher uptake of Fe, Mn, Zn, Cu and B were recorded in treatment T₁₂ receiving 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution (5563, 2027, 694.0, 149.9, and 112.8 g ha⁻¹) compared to all the other treatments. Similar trend was observed during 2014.
- The salt and organic carbon contents of soil after the harvest of tomato crop were significantly higher in treatment T₂ which received 100% RDF + 5 sprays of undiluted distillery spentwash (0.33, 0.49 dSm⁻¹ and 0.74, 0.78 % during 2013 and 2014, respectively) compared to all other treatments.
- Significantly higher available nitrogen, phosphorus and potassium content of soil 268.4, 34.6 and 383.0 kg ha⁻¹, respectively during 2013 was observed in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash. Similar trend was observed in the 2014.
- Significantly higher exchangeable calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash (7.62, 3.57, 0.98 c mol (p+) kg⁻¹ and 22.5mg kg⁻¹, respectively) compared to all other treatments during 2013.
- There was no significant variation in the DTPA extractable micronutrients and available boron contents of soil and the values were higher in most of the treatments during 2014 compared to 2013. Higher DTPA extractable iron, manganese, zinc, copper, and available boron content of soil were observed in treatment T₂ receiving 100% RDF + 5 sprays of undiluted distillery spentwash (9.3, 5.78, 1.50, 0.71, and 0.22 mg kg⁻¹, respectively) compared to all the other treatments during 2013.

Experiment-II: To determine the optimum proportion of nutrients for preparation of fortified spentwash and to study the effect of fortified spentwash on growth and yield of tomato and soil properties.

- All the growth parameters at different growth stages and yield parameters at harvest of tomato were significantly influenced by the foliar application of fortified distillery spentwash.
- Significantly higher plant height and number of branches per plant during 60 DAS (124.5 cm and 7.8 respectively) were observed with treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval compared to all other treatments.
- Significantly higher SPAD meter reading was observed during 2013 and 2014 in the treatment T₇ which received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (T₇: 24.2 and 20.5 respectively). Lower SPAD meter reading was observed in treatment T₁₁ receiving RDF with water spray during 2013 and 2014 (13.8 and 13.0, respectively). Similar trend was observed at 90 DAT and at harvest.
- The highest number of fruits per plant was observed during 2013 than during 2014 (69.3 and 59.4, respectively) in T₇ treatment receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval and was on par with T₆ treatment receiving 90% RDN through fertilizers+ 10% RDN through 2 sprays of fortified SW 2 at 30 days interval (T₆: 66.6 and 56.5, respectively).
- The higher yield was recorded due to application of fortified SW 2 (fortified with nitrogen, zinc and boron) compared to foliar application of SW 1 (fortified with nitrogen) and water spray.
- Higher fruit yield was recorded in the treatment T₇ which received 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (8.15, 6.94 kg plant⁻¹ and 89.7, 76.4 t ha⁻¹, respectively), significantly lower fruit yield (6.14, 5.60 kg plant⁻¹ and 67.7, 62.0 t ha⁻¹, respectively) was observed in T₅ treatment which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.
- Significantly higher TSS values, ascorbic acid and lycopene were observed during 2013 in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (6.4, 65.3 and 18.2 mg 100⁻¹ g, respectively) when compared to the other treatments. Similar trend was recorded in the 2014.
- Foliar application of SW 2 (fortified with nitrogen, zinc and boron) recorded higher nutrient concentration and nutrient uptake by tomato plant compared to SW 1 (fortified with nitrogen).

- Nitrogen, phosphorus and potassium concentration in tomato fruit was significantly higher in T₇ treatment that received 85% RDN through fertilizers + 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (2.58, 0.44, 2.90 % and 2.18, 0.31, 2.60 %) compared to all the other treatments. Lower nitrogen, phosphorus and potassium concentration was noticed in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (2.30, 0.28, 2.49 and 1.85, 0.16, 2.20 %) during 2013 and 2014, respectively.
- Significantly higher concentrations of Fe, Mn, Zn, Cu, and B were observed in treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (590.3, 200.5, 98.20, 16.0, 11.2 mg kg⁻¹ and 532.5, 182.3, 60.20, 13.50, 10.9 mg kg⁻¹, respectively) compared to all the other treatments during 2013 and 2014.
- During both the years (2013 and 2014) nitrogen, phosphorus and potassium concentration in tomato haulm (Table 59) was significantly higher in T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (1.71, 0.41, 1.98 % and 1.46, 0.33, 1.53 %, respectively) compared with treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (1.50, 0.27, 1.69 % and 1.21, 0.17, 1.25 % respectively).
- Higher concentrations of Fe, Mn, Zn, Cu, and B (pooled) were recorded in T₇ treatment that received 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (508.7, 171.4, 84.5, 14.60 and 10.8 mg kg⁻¹, respectively) compared to all other treatments. Lower concentrations of Fe, Mn, Zn, Cu, and B (380.8, 97.9, 51.7, 10.95 and 9.1 mg kg⁻¹, respectively) were observed in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval.
- During both 2013 and 2014, significantly higher nitrogen, phosphorus and potassium uptake by tomato crop was recorded in the treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (219.8, 42.6, 253.4 and 176.5, 30.1, 211.6 kg ha⁻¹, respectively) compared to treatment T₅ (173.7, 23.4, 190.9 and 136.9, 13.4, 160.0 kg ha⁻¹, respectively) which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval .
- Higher uptake of Fe, Mn, Zn, Cu, and B were recorded in treatment T₇ receiving 85% RDN through fertilizers+ 15% RDN through 3 sprays of fortified SW 2 at 20 days interval (5674, 1915 791.7, 157.4 and 110.7g ha⁻¹) compared to all the other treatments during 2013.
- Significantly higher pH and electrical conductivity of soil was observed in treatment T₅ which received 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (7.98, 0.31 dSm⁻¹ and 7.98, 0.45 dSm⁻¹ during 2013

and 2014, respectively) compared to all the other treatments. However, significantly higher available phosphorus and potassium content was noticed in the treatment T₅ which received 70% RDN through fertilizers + 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (30.6 and 395.4 kg ha⁻¹).

- Significantly higher exchangeable calcium, magnesium, sodium and available sulphur contents of soil were observed in treatment T₅ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 1 at 10 days interval (8.6, 4.6, 0.91 c mol (p+) kg⁻¹ and 22.7 mg kg⁻¹, respectively) compared to all the other treatments during 2013.
- Higher DTPA extractable iron, manganese, zinc, copper and available boron contents (pooled) of soil after harvest of tomato crop were observed in the treatment T₁₀ receiving 70% RDN through fertilizers+ 30% RDN through 6 sprays of fortified SW 2 at 10 days interval (16.9, 5.88, 3.04, 1.65 and 0.57 mg kg⁻¹, respectively) compared to all the other treatments.
- The available nutrient status of soil after harvest of tomato crop was higher in 2014 compared to 2013.
- Foliar application of fortified SW 2 (fortified with nitrogen, zinc and boron) recorded significantly higher growth, yield, quality of tomato and also increases the nutrient concentration and nutrient uptake by tomato crop than foliar application of fortified SW 1 (fortified with nitrogen).

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*Originals not seen

Appendix 1: Cost of inputs used and price of output

Sl. No.	Particulars	Price (Rs.)/unit
I.	INPUTS	
1	Tomato seedlings	0.4 seedling ⁻¹
2	Fertilizers	
	a. Urea	6.0 kg ⁻¹
	b. Single Super Phosphate	6.4 kg ⁻¹
	c. Muriate of Potash	16 kg ⁻¹
	d. Liquid ammonia	220 L ⁻¹
	d. Zinc sulphate	33 kg ⁻¹
	e. Borax	520 kg ⁻¹
3	Organic Manures	
	a. FYM	750 t ⁻¹
4	Plant protection chemicals	
	a. Chlorpyrifos	380 L ⁻¹
	b. Copper oxychloride	700 kg ⁻¹
	c. Super confider	4600 L ⁻¹
	d. Acrobat	5500 kg ⁻¹
	e. Flame	19000 L ⁻¹
	f. Ridomil Gold	1800 kg ⁻¹
5	Labour Wages	
	a. Men	150 day ⁻¹
	b. Women	100 day ⁻¹
	c. Bullock pair with a man	500 day ⁻¹
	d. Bullock cart with a man	500 day ⁻¹
	e. Tractor	650 hr ⁻¹
6	Staking materials	
	Stacking poles	6 pole ⁻¹
	Staking wires	80 kg ⁻¹
	Cotton trades	60 kg ⁻¹
II.	OUT PUTS	
	Tomato fruits	5.0 kg ⁻¹

Table: 68a.Economics of tomato cultivation as influenced by foliar application of diluted distillery spentwash .

Treatment	Cost of cultivation			Gross returns			Net returns			B:C ratio		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T₁	121510	120760	121135	306000	280000	293000	184490	159240	171865	2.52	2.32	2.42
T₂	121960	121210	121585	315000	287000	301000	193040	165790	179415	2.58	2.37	2.48
T₃	121510	120760	121135	343500	294500	319000	221990	173740	197865	2.83	2.44	2.63
T₄	121960	121210	121585	349000	298500	323750	227040	177290	202165	2.86	2.46	2.66
T₅	121510	120760	121135	366500	311500	339000	244990	190740	217865	3.02	2.58	2.80
T₆	121960	121210	121585	384000	313000	348500	262040	191790	226915	3.15	2.58	2.87
T₇	121510	120760	121135	387000	337000	362000	265490	216240	240865	3.18	2.79	2.99
T₈	121960	121210	121585	400500	337500	369000	278540	216290	247415	3.28	2.78	3.03
T₉	121510	120760	121135	404000	341500	372750	282490	220740	251615	3.32	2.83	3.08
T₁₀	121960	121210	121585	415500	364000	389750	293540	242790	268165	3.41	3.00	3.21
T₁₁	121510	120760	121135	404500	356000	380250	282990	235240	259115	3.33	2.95	3.14
T₁₂	121960	121210	121585	422000	367000	394500	300040	245790	272915	3.46	3.03	3.24
T₁₃	121960	121210	121585	287000	270500	278750	165040	149290	157165	2.35	2.23	2.29

Legend:T₁: 100% RDF + 4 sprays of undiluted distillery spentwashT₂: 100% RDF + 5 sprays of undiluted distillery spentwashT₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilutionT₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilutionT₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilutionT₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilutionT₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilutionT₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilutionT₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilutionT₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilutionT₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilutionT₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilutionT₁₃: 100% RDF + water sprays (5 times)**Note:** RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

Table: 68b. Economics of tomato cultivation as influenced by foliar application of diluted distillery spentwash .

Treatment	Cost of cultivation			Gross returns			Net returns			B:C ratio		
	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled	2013	2014	Pooled
T ₁	121510	120760	121135	306000	280000	293000	184490	159240	171865	2.52	2.32	2.42
T ₂	121960	121210	121585	315000	287000	301000	193040	165790	179415	2.58	2.37	2.48
T ₃	121510	120760	121135	343500	294500	319000	221990	173740	197865	2.83	2.44	2.63
T ₄	121960	121210	121585	349000	298500	323750	227040	177290	202165	2.86	2.46	2.66
T ₅	121510	120760	121135	366500	311500	339000	244990	190740	217865	3.02	2.58	2.80
T ₆	121960	121210	121585	384000	313000	348500	262040	191790	226915	3.15	2.58	2.87
T ₇	121510	120760	121135	387000	337000	362000	265490	216240	240865	3.18	2.79	2.99
T ₈	121960	121210	121585	400500	337500	369000	278540	216290	247415	3.28	2.78	3.03
T ₉	121510	120760	121135	404000	341500	372750	282490	220740	251615	3.32	2.83	3.08
T ₁₀	121960	121210	121585	415500	364000	389750	293540	242790	268165	3.41	3.00	3.21
T ₁₁	121510	120760	121135	404500	356000	380250	282990	235240	259115	3.33	2.95	3.14
T ₁₂	121960	121210	121585	422000	367000	394500	300040	245790	272915	3.46	3.03	3.24
T ₁₃	121960	121210	121585	287000	270500	278750	165040	149290	157165	2.35	2.23	2.29

Legend:

T₁: 100% RDF + 4 sprays of undiluted distillery spentwash
T₂: 100% RDF + 5 sprays of undiluted distillery spentwash
T₃: 100% RDF + 4 sprays of distillery spentwash at 1:1 dilution
T₄: 100% RDF + 5 sprays of distillery spentwash at 1:1 dilution
T₅: 100% RDF + 4 sprays of distillery spentwash at 1:2 dilution
T₆: 100% RDF + 5 sprays of distillery spentwash at 1:2 dilution
T₇: 100% RDF + 4 sprays of distillery spentwash at 1:3 dilution

T₈: 100% RDF + 5 sprays of distillery spentwash at 1:3 dilution
T₉: 100% RDF + 4 sprays of distillery spentwash at 1:4 dilution
T₁₀: 100% RDF + 5 sprays of distillery spentwash at 1:4 dilution
T₁₁: 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution
T₁₂: 100% RDF + 5 sprays of distillery spentwash at 1:5 dilution
T₁₃: 100% RDF + water sprays (5 times)

Note: RDF - 180:120:150 kg NPK ha⁻¹ and FYM 25 t ha⁻¹ common to all the treatments

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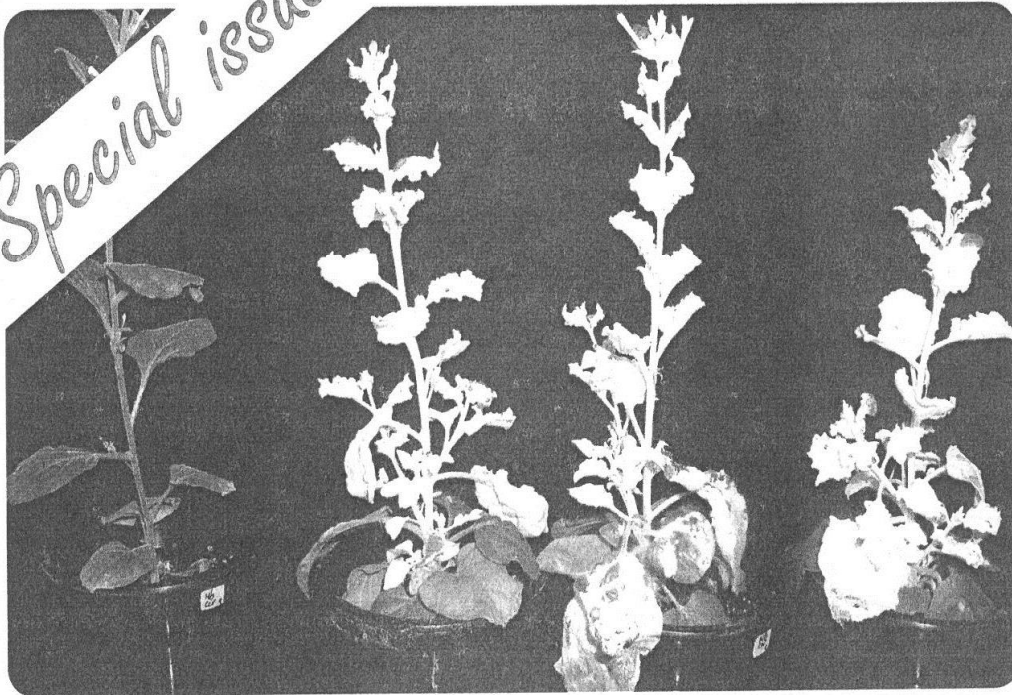
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Special issue



Post-transcriptional silencing of phytoene desaturase gene



**UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU, INDIA**

Effect of Foliar Application of Diluted Distillery Spentwash on Growth, Yield and Quality of Tomato and Soil Properties

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ABSTRACT

An experiment was conducted to study the effect of foliar application of different dilutions of distillery spentwash to tomato crop during 2013 in a farmer's field at Gurudevahalli, Mandya district. Foliar application of 1:5 dilution of distillery spentwash recorded significantly higher growth, yield and quality parameters of tomato. Significantly higher fruit yield (84.4 t ha⁻¹) was recorded with 5 sprays of distillery spentwash at 1:5 dilution followed by 5 sprays of distillery spentwash at 1:4 dilution (83.1 t ha⁻¹) and lower fruit yield (61.2 t ha⁻¹) was recorded with 5 sprays of undiluted distillery spentwash. The highest NPK content in soil after harvest of tomato crop was noticed in treatment receiving foliar application of undiluted distillery spentwash and lower was recorded when 5 sprays of distillery spentwash at 1:5 dilution was provided.

MOLASSES an important byproduct of sugar industry is the main raw material for the production of alcohol in distilleries by fermentation method. About 40 billion liters of waste water annually discharged by distilleries, known as raw spentwash (RSW), is characterized by high biological oxygen demand (BOD:39000-42000 mg/l) and chemical oxygen demand (COD: 79000- 92000 mg/l) (Joshi, 1994). Discharge of RSW into open land or water bodies results in pollution of soil and water which in turn affects plant and animal lives. Hence disposal of spentwash is a major problem. It is therefore, necessary to find out ways and means of using distillery spentwash as a source of nutrients and water without causing pollution. In this direction, attempts were made to evaluate distillery spentwash as foliar nutrition source at different dilutions and to study its impact on growth and yield parameters, yield and quality of tomato.

The primary treated distillery spentwash of bimethanation plant from M/S Sri Chamundeswari Sugars Ltd. located at Bharathi Nagar, Mandya district, Karnataka was used in the present study and analysed for physico-chemical properties and nutrients composition using standard methods (Manivasakam, 1987). A field experiment was conducted during *Kharif* 2013 in a farmer's field at Gurudevahalli, Maddur taluk, Mandya district, Karnataka to find out the response to foliar application of diluted distillery spentwash on growth, yield and quality parameters of

tomato. The soil of the experimental field was sandy loam in texture with alkaline reaction (7.81), normal in electrical conductivity (0.15 dSm⁻¹), low in organic carbon (0.42 %). The soil was low in available nitrogen (223.2 kg ha⁻¹), medium in phosphorus (30.5 kg ha⁻¹) and high in potassium (360.5 kg ha⁻¹). The experiment consisted thirteen treatments. All the treatments received 100 per cent RDF (180, 120, and 150 kg NPK ha⁻¹) along with FYM (25 t ha⁻¹). The treatments tried were T₁:100 per cent RDF + 4 sprays of undiluted distillery spentwash, T₂:100 per cent RDF + 5 sprays of undiluted distillery spentwash, T₃:100 per cent RDF + 4 sprays of distillery spentwash at 1:1 dilution, T₄:100% RDF + 5 sprays of distillery spentwash at 1:1 dilution, T₅:100% RDF + 4 sprays of distillery spentwash at 1:2 dilution, T₆:100 per cent RDF + 5 sprays of distillery spentwash at 1:2 dilution, T₇:100 per cent RDF + 4 sprays of distillery spentwash at 1:3 dilution, T₈:100 per cent RDF + 5 sprays of distillery spentwash at 1:3 dilution, T₉:100 per cent RDF + 4 sprays of distillery spentwash at 1:4 dilution, T₁₀:100 per cent RDF + 5 sprays of distillery spentwash at 1:4 dilution, T₁₁:100 per cent RDF + 4 sprays of distillery spentwash at 1:5 dilution, T₁₂:100 per cent RDF + 5 sprays of distillery spentwash at 1:5 dilution, T₁₃:100 per cent RDF + water spray (5 times). Recommended package of practices was followed in raising the crop and control of pests and diseases. Foliar application of distillery spentwash was started after 40 days of transplanting at ten days interval. Observations on

growth, yield and quality parameters were recorded and the data were statistically analyzed following the standard procedures (Sundararaj *et al.*, 1972).

The distillery spentwash was neutral in reaction (pH-7.32) and high in electrical conductivity (28.5 dSm⁻¹). The total nitrogen, phosphorus and potassium contents were 0.12, 0.04 and 1.02 per cent, respectively. The sodium, calcium, magnesium, chloride and sulphate concentration was 645, 1452, 790, 4783 and 672 mg l⁻¹ respectively. Total dissolved solids content was 3.40

per cent. The iron, zinc, copper, manganese and boron contents were 22.5, 6.52, 2.32, 4.28 and 1.08 mg l⁻¹ respectively.

The growth, yield parameters and yield increased with decrease in the concentration of distillery spentwash (Table I). Treatment T₁₂ receiving 100 per cent RDF + 5 sprays of distillery spentwash at 1:5 dilution recorded significantly taller plants, more number of branches plant⁻¹, higher SPAD reading, fruit set percent, yield per plant and yield per hectare (142.3 cm,

TABLE I

Effect of foliar application of diluted distillery spentwash on growth, yield parameters and yield of tomato crop

Treatments	Plant height (cm)	No. of Branches plant ⁻¹	SPAD reading	Fruit set per cent (%)	Yield (kg plant ⁻¹)	Yield (t ha ⁻¹)
T ₁ :100% RDF + 4 sprays of undiluted distillery spentwash	108.6	9.0	13.1	67.2	5.67	63.0
T ₂ :100% RDF + 5 sprays of undiluted distillery spentwash,,	105.6	8.5	13.2	64.8	5.50	61.2
T ₃ :100% RDF + 4 sprays of DSW at 1:1 dilution	111.6	10.9	15.2	68.0	6.18	68.7
T ₄ :100% RDF + 5 sprays of DSW at 1:1 dilution	112.0	11.2	16.1	72.9	6.28	69.8
T ₅ :100% RDF + 4 sprays of DSW at 1:2 dilution	126.4	10.7	17.6	77.3	6.60	73.3
T ₆ :100% RDF + 5 sprays of DSW at 1:2 dilution,	127.8	11.3	19.6	80.9	6.92	76.8
T ₇ :100% RDF + 4 sprays of DSW at 1:3 dilution,	130.6	11.6	19.4	80.4	6.97	77.4
T ₈ :100% RDF + 5 sprays of DSW at 1:3 dilution	133.6	11.9	19.6	81.1	7.21	80.1
T ₉ :100% RDF + 4 sprays of DSW at 1:4 dilution,	134.5	11.8	20.4	81.5	7.27	80.8
T ₁₀ :100% RDF + 5 sprays of DSW at 1:4 dilution	139.6	11.9	21.1	80.8	7.48	83.1
T ₁₁ :100% RDF + 4 sprays of DSW at 1:5 dilution,	137.5	11.7	21.1	80.0	7.28	80.9
T ₁₂ :100% RDF + 5 sprays of DSW at 1:5 dilution	142.3	12.1	22.5	81.8	7.60	84.4
T ₁₃ :100% RDF + water spray (5 times)	104.7	8.3	12.7	63.7	5.16	57.4
S.Em±	6.2	0.5	1.1	4.5	0.33	4.0
CD@5%	18.1	1.6	3.1	13.2	0.98	11.6
CV	8.64	8.52	10.25	10.42	8.74	9.34

Note: DSW- Distillery spentwash

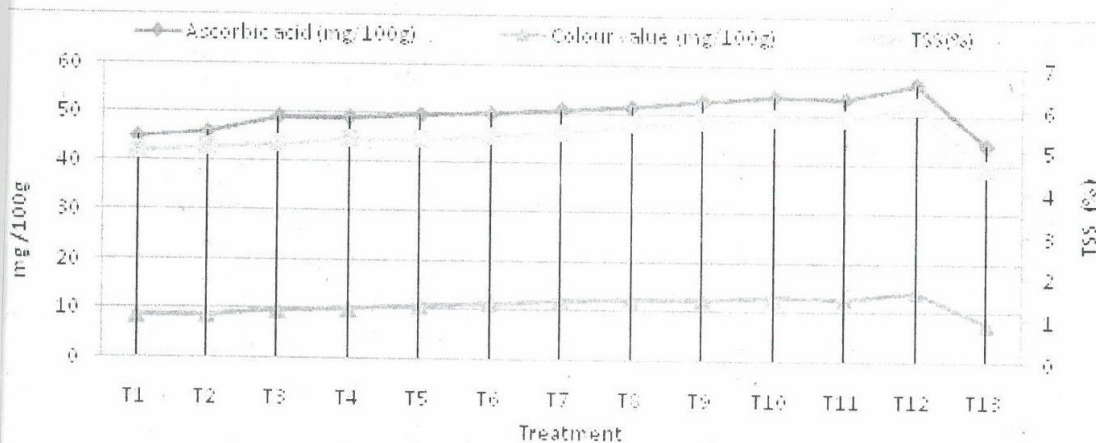
12.1, 22.5, 81.8%, 7.60 kg and 84.4 t ha⁻¹, respectively). This could be due to higher dilution of distillery spentwash resulting in lower concentration of salts which has not affected the metabolic activities of tomato plant. Similar observation was recorded by Zalawadia *et al.* (1997). While, significantly lower growth, yield and yield parameters were recorded in the treatment receiving 100 per cent RDF + 5 water sprays (104.7cm, 8.3, 12.7, 63.7%, 5.16 kg and 57.4 t ha⁻¹, respectively). The reduction in growth and yield of tomato in treatment T₁₃ compared to all other treatments is attributed to spraying of water which contain no nutrients.

Foliar application of diluted distillery spentwash influenced the quality parameters of tomato (Fig. 1). The maximum concentration of ascorbic acid (56.7 mg 100g⁻¹), TSS (6.1%) and colour value (14.5mg 100g⁻¹) were recorded in the treatment receiving 100 per cent RDF + 5 sprays of distillery spentwash at 1:5 dilution and it was on par with 100 per cent RDF + 5 sprays of distillery spentwash at 1:4 dilution (56.7mg100g⁻¹, 6.1% and 14.5mg 100g⁻¹, respectively). This may be attributed to the optimum levels of macro and micro nutrients available to the plants at 1:5 and

1:4 dilutions of distillery spentwash. The minimum concentration of ascorbic acid (44.2 mg 100g⁻¹), TSS (4.6%) and colour value (8.0 mg 100g⁻¹) were recorded in treatment receiving 100 per cent RDF + 5 water sprays.

The changes in soil chemical properties due to foliar application of diluted distillery spentwash are presented in Table II. There was no significant variation in the soil reaction due to treatments. Significantly higher EC value (0.33 dSm⁻¹) was recorded in the treatment receiving 100 per cent RDF + 5 sprays of undiluted distillery spentwash while lower EC value was recorded in the control (0.14 dSm⁻¹). This may be due to accumulation of soluble salts on soil surface during foliar application of distillery spentwash. This is in line with the findings of Joshi *et al.* (1996) who reported that soil application of distillery spentwash increased the EC after wheat harvest in the surface layer of soil (0-15 cm).

Significantly higher available nitrogen, phosphorus and potassium contents (268.4, 34.6 and 383.4 kg ha⁻¹) of soil were recorded in the treatment receiving 100 per cent RDF + 5 sprays of undiluted distillery



T₁:100% RDF + 4 sprays of UDSW, T₂:100% RDF + 5 sprays of UDSw, T₃:100% RDF + 4 sprays of DSW at 1:1 dilution, T₄:100% RDF + 5 sprays of DSW at 1:1 dilution, T₅:100% RDF + 4 sprays of DSW at 1:2 dilution, T₆:100% RDF + 5 sprays of DSW at 1:2 dilution, T₇:100% RDF + 4 sprays of DSW at 1:3 dilution, T₈:100% RDF + 5 sprays of DSW at 1:3 dilution, T₉:100% RDF + 4 sprays of DSW at 1:4 dilution, T₁₀:100% RDF + 5 sprays of DSW at 1:4 dilution, T₁₁:100% RDF + 4 sprays of DSW at 1:5 dilution, T₁₂:100% RDF + 5 sprays of DSW at 1:5 dilution, T₁₃:100% RDF + water spray (5 times).

Fig 1. Quality parameters of tomato as affected by foliar application of diluted distillery spentwash

TABLE II

Effect of foliar application of diluted distillery spentwash on pH, EC and available NPK content of soil after harvest of tomato crop

Treatments	pH	EC (dSm ⁻¹)	NPK		
			N	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O
T ₁ :100% RDF + 4 sprays of undiluted distillery spentwash	7.64	0.32	265.4	33.7	382.3
T ₂ :100% RDF + 5 sprays of undiluted distillery spentwash,	7.65	0.33	268.4	34.6	383.0
T ₃ :100% RDF + 4 sprays of DSW at 1:1 dilution	7.64	0.31	236.2	30.4	379.5
T ₄ :100% RDF + 5 sprays of DSW at 1:1 dilution	7.67	0.30	241.0	30.9	381.4
T ₅ :100% RDF + 4 sprays of DSW at 1:2 dilution	7.65	0.31	223.2	28.4	381.2
T ₆ :100% RDF + 5 sprays of DSW at 1:2 dilution,	7.63	0.31	220.4	29.6	370.1
T ₇ :100% RDF + 4 sprays of DSW at 1:3 dilution	7.62	0.32	219.7	27.8	371.4
T ₈ :100% RDF + 5 sprays of DSW at 1:3 dilution	7.60	0.30	226.9	28.3	363.7
T ₉ :100% RDF + 4 sprays of DSW at 1:4 dilution	7.63	0.31	206.1	26.5	360.0
T ₁₀ :100% RDF + 5 sprays of DSW at 1:4 dilution	7.61	0.29	215.5	27.1	351.4
T ₁₁ :100% RDF + 4 sprays of DSW at 1:5 dilution	7.65	0.28	192.5	25.4	334.5
T ₁₂ :100% RDF + 5 sprays of DSW at 1:5 dilution	7.64	0.27	195.2	26.3	338.5
T ₁₃ :100% RDF + water spray (5 times)	7.79	0.14	227.0	28.1	356.6
S.Em±	0.06	0.02	15.3	1.7	11.1
CD@5%	NS	0.06	44.8	5.0	32.4
CV		12.60	11.76	10.25	5.26

Note : DSW - Distillery spentwash

spentwash. Lower NPK contents (192.5, 25.4 and 334.9 NPK kg ha⁻¹) were observed in the treatment receiving 100% RDF + 4 sprays of distillery spentwash at 1:5 dilution.

In the present investigation, it was apparent that foliar application of 1:4 or 1:5 diluted distillery spentwash enhanced most of the plant growth and yield parameters of tomato, thereby increasing the uptake of nutrients resulting in increased crop productivity.

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Effect of Distillery Spentwash on Growth Regulating Properties of Cowpea, Sunflower and Tomato

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ABSTRACT

A laboratory experiment was conducted to study the effect of different dilutions of distillery spentwash {undiluted, 1:1, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8, 1:9, 1:10 and control (tap water)} on seed germination (%), speed of germination, shoot length, root length, and seedling vigour of cowpea, sunflower and tomato. The distillery spentwash did not show any inhibitory effect on seed germination and speed of germination at higher dilution except in tomato. Irrespective of the crop species, at higher concentrations (undiluted and <1:5) low germination per cent or complete failure of germination was observed. The root, shoot length and vigour index values also followed a similar trend. It was found that a concentration of 1:5 dilution was ideal for germination of cowpea and sunflower seeds, and 1:8 dilution was ideal for tomato seed. Based on the observation, the tolerance of the crops to distillery spentwash has been arranged in the order: cowpea >sunflower >tomato. It can be concluded that the effect of the distillery spentwash is crop-specific and due care should be taken before using it for seed treatment and pre-sowing irrigation purposes.

Key words: Distillery effluent, Cowpea, Sunflower, Tomato, Germination (%)

The safe disposal of industrial effluents on land for irrigation is comparatively a new area of research and hence throws new challenges for environmental management (Buechler and Mekala 2005). The research work to lessen the deleterious effect of industrial effluents on life and surroundings is essential for developing strategies for disposal. The approach is much provide environmentally compatible solution to water pollution problems and augments the traditional irrigational resources for the development of sustainable agriculture. The industrial effluents contain large amounts of nutrients as well as toxic elements. Plants are being used as ecological indicators to assess the toxicity of pollutants. Increasing number of industries in India has resulted in substantial increase in pollutants load affecting our environment. Among various industries, molasses based industries (distilleries) occupy a prominent place in Indian economy. The distilleries are considered as a major polluter of the environment and are one of the 17 most polluting industries listed by the Central Pollution Control Board. At present, there are 319 distilleries in India with an installed capacity of 3.29 billion litre of alcohol (Malaviya and Sharma 2011). The distillery spentwash is characterized by high chemical oxygen demand (COD), biochemical oxygen demand

(BOD), phenolic compounds, sulphate and heavy metals (Pant and Adholeya 2007). In India, with the current emphasis on environmental health and water pollution issues, there is an increased awareness on the need to dispose of distillery spentwash safely and beneficially. Use of spentwash in agriculture could be an important consideration when its disposal is being planned. The use of distillery spentwash in agriculture is popular since the inception of the industry. In water scarce situation spentwash is an important water source for irrigation, causes positive effect at lower concentrations on this aspect studies have been carried out by many researchers (Rani and Srivastava 1990, Subramani 1995, Pandey *et al.* 2007). The present study is an effort to characterize the distillery spentwash for its physico-chemical parameters and to study its germination and growth regulating properties on cowpea, sunflower and tomato seeds at different dilutions.

MATERIALS AND METHODS

The primary treated distillery spentwash coming out of biomethanation plant used in the present study was collected at bimonthly intervals from M/S Sri Chamundeswari Sugars Ltd., located near Bengaluru (Karnataka), India, and was analyzed for physico-chemical properties and nutrients

composition by using standard methods (Manivasakam 1987).

Laboratory experiment under in-vitro conditions

The experiment was conducted in the post graduate laboratory of the Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences (GKVK), Bengaluru with eleven different concentrations of distillery spent wash (undiluted, 1:1, 1:2, 1:3, 1:4, 1:5, 1:6, 1:7, 1:8, 1:9 and 1:10) and control (tap water). Cowpea (*Vigna radiata*, var. – PBW 343), sunflower (*Helianthus annuus*, var. – KBSH 54) and tomato (*Lycopersicon esculentum*, var. – NS 501) seeds were used. Each treatment was replicated thrice and the experimental design was CRD for the study. Seeds were surface sterilized with 0.1% HgCl₂ and glass wares were autoclaved before use. Seeds were soaked with respective dilution of treated spentwash and kept overnight and placed on filter paper in each Petri dish and equal quantity of diluted spentwash was added and in control tap water was added. Seed germination (%), root length (cm), shoot length (cm) and vigour index of seedlings were recorded upto 7 days at 24 hours interval.

Calculation of germination percent, speed of germination, seed vigour index, shoot length and root length

Germination percentage was calculated by dividing the number of seed germinated on each day by total number of seeds taken × 100, and finally adding the total percentage. Shoot and root length were measured by using a scale; Seed vigour index was calculated as per the formula: SVI = % of germination × Seedling length (cm) as given by Jain and Saha (1971).

Speed of germination was calculated using the formula:

Speed of germination = No. of seeds germinated/Days of first count + --- + No. of seeds germinated/Days of final count.

The experimental data was analyzed statistically for test of significance as explained by Fisher's method of analysis of Variance.

RESULTS AND DISCUSSION

The distillery spentwash was collected at bimonthly interval during December 2013 to April 2014. The results are presented in the (Table 1). The distillery spentwash was brown in colour, neutral in reaction (pH 7.32). Electrical conductivity was high (28.5 dS m⁻¹). The total N, P₂O₅ and K₂O contents were 0.12, 0.04 and 1.02 percent, respectively. The Na, Ca, Mg and SO₄ concentration was 645, 1452, 790 and 672 (mg/l), respectively. Total dissolved solids content was 3.40%. The micronutrients content of the spent wash was low (Fe, Zn, Cu, Mn, values were 22.5, 6.52, 2.32, 4.28 mg/l, respectively). The chloride and boron content of spent wash was 4783 and 1.08 mg/l respectively.

Table 1 Physico-chemical properties of primary spentwash sample collected from Chamundeswari Sugars Ltd

Parameters	Mean
pH	7.32
EC (dS/m)	28.5
Total N (%)	0.12
Total P ₂ O ₅ (%)	0.04
Total K ₂ O (%)	1.02
Na (mg/l)	645
Ca (mg/l)	1452
Mg (mg/l)	790
TDS (%)	3.40
Cl (mg/l)	4783
SO ₄ (mg/l)	672
Fe (mg/l)	22.5
Zn (mg/l)	6.52
Cu (mg/l)	2.32
Mn (mg/l)	4.28
B (mg/l)	1.08

Table 2 Germination per cent of cowpea, sunflower and tomato seeds under different dilutions of distillery spent wash

Treatments	Cowpea				Sunflower					Tomato			
	2 nd day	3 rd day	4 th day	5 th day	2 nd day	3 rd day	4 th day	5 th day	2 nd day	3 rd day	4 th day	5 th day	
T ₁ (Undiluted)	0.00	0.00	20.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
T ₂ (1:1 dilution)	0.00	10.0	26.6	36.6	0.0	41.6	46.7	61.7	0.0	0.0	0.0	0.0	
T ₃ (1:2 dilution)	20.0	36.6	56.6	63.3	15.0	61.6	70.0	80.0	0.0	0.0	0.0	0.0	
T ₄ (1:3 dilution)	46.6	63.3	80.0	90.0	30.0	70.0	76.7	86.7	0.0	0.0	0.0	0.0	
T ₅ (1:4 dilution)	56.6	83.3	86.6	93.3	45.0	73.3	83.3	95.0	0.0	0.0	10.0	50.0	
T ₆ (1:5 dilution)	80.0	96.6	100.0	100.0	63.3	83.3	86.7	100.0	0.0	0.0	10.0	50.0	
T ₇ (1:6 dilution)	83.3	100.0	100.0	100.0	65.0	86.6	100.0	100.0	15.0	25.0	51.6	83.3	
T ₈ (1:7 dilution)	78.3	100.0	100.0	100.0	60.0	88.3	95.0	100.0	15.0	30.0	60.0	86.6	
T ₉ (1:8 dilution)	80.0	100.0	100.0	100.0	58.3	88.3	100.0	100.0	20.0	31.6	93.3	100.0	
T ₁₀ (1:9 dilution)	80.0	98.3	100.0	100.0	60.0	86.6	100.0	100.0	25.0	40.0	96.6	100.0	
T ₁₁ (1:10 dilution)	80.0	100.0	100.0	100.0	58.3	88.3	90.0	100.0	30.0	50.0	96.6	100.0	
T ₁₂ (Control)	80.0	100.0	100.0	100.0	65.0	90.0	100.0	100.0	36.6	50.0	100.0	100.0	
S. Em±	1.52	1.98	1.67	2.36	1.18	1.86	2.10	1.60	0.48	0.48	0.96	1.18	
C. D. at 1 %	6.02	7.85	6.59	9.32	4.66	7.37	8.30	6.31	1.90	1.90	3.81	4.66	
CV	4.62	4.64	3.57	4.83	4.71	4.51	4.60	3.24	7.06	4.41	3.93	3.85	

The crop species differed widely in their response to different dilutions of distillery spentwash with respect to germination (%), speed of germination, root length, shoot length and vigour index. At higher concentrations, the

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illery spentwash showed inhibitory effect on seed germination in all the crops. Inhibition of seed germination may be due to high concentration of dissolved salts, which increase the salinity and conductivity of the absorbed solute before germination (Gautam *et al.* 1992, Singh *et al.* 2006). Seed germination in all the three crop species, has increased with decrease in the effluent concentration. The reason for the reduction in germination percent at higher concentration of distillery spentwash in all the crops could be attributed to higher concentration of inorganic salts (Table 1) and consequently its higher EC values. The EC of spentwash was higher at lower dilutions. The germination percent was gradually increased from 2nd to 5th day in all the crops (Table 2). In cowpea and sunflower crops, 100% germination was observed from 1:5 dilution to 1:10 dilution (spentwash:water) at 5th day. This may be

attributed to the presence of nutrients like N, P, K, Ca and Mg in the effluent at optimum concentration which promoted the growth of plant (Kakar *et al.* 2010). A very poor or no germination was recorded in 1:1 dilution and undiluted spentwash. At lower dilution (<1:4), there was a very large fungal growth on the seeds, which may also have been one of the factors responsible for poor germination at lower dilution. These results are in conformity with the findings of earlier workers (Neelam and Sahai 1988, Pandey and Sony 1994) who also observed a decrease in seed germination with increase in the concentration of the effluent. Similar results were reported by Subramani *et al.* (1995) while studying the effect of distillery effluent on *Vigna radiata*. Ramana *et al.* (2001) also observed similar kind of inhibitory effects in mustard, cauliflower and radish seed germination.

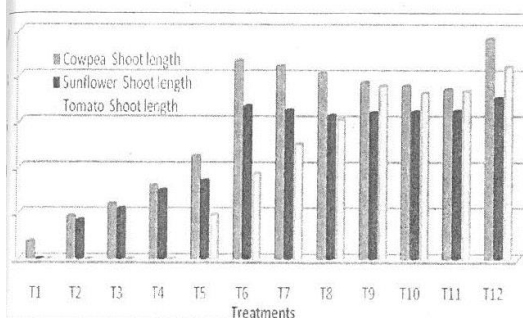


Fig 1 Shoot length of cowpea, sunflower and tomato seeds upon germination as influenced by distillery spentwash at different dilutions

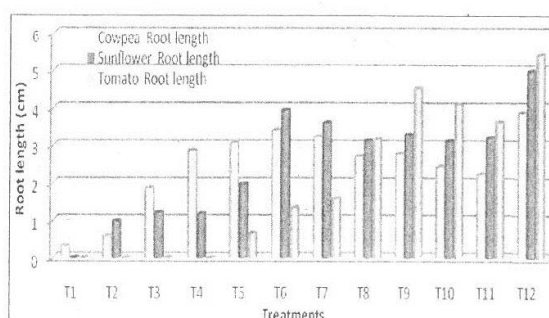


Fig 2 Root length of cowpea, sunflower and tomato seeds upon germination as influenced by distillery spentwash at different dilutions

Table 3 Seedling vigour index and speed of germination of cowpea, sunflower and tomato seeds under different dilutions of distillery spent wash

Treatments	Speed of germination			Seedling Vigour index		
	Cowpea	Sunflower	Tomato	Cowpea	Sunflower	Tomato
(Undiluted)	11	0	0	32	0	0
(1:1 dilution)	17	38	0	89	164	0
(1:2 dilution)	49	62	0	269	272	0
(1:3 dilution)	82	75	0	543	363	0
(1:4 dilution)	96	87	3	703	511	43
(1:5 dilution)	117	101	13	1201	1061	253
(1:6 dilution)	120	106	45	1164	1008	550
(1:7 dilution)	118	103	50	1079	939	801
(1:8 dilution)	118	104	64	1045	966	1208
(1:9 dilution)	118	104	70	998	953	1134
(1:10 dilution)	118	101	76	962	966	1095
(Control)	118	108	80	1342	1200	1379
S. Em±	1.47	1.35	0.44	19.48	14.76	11.78
C. D. at 1 %	5.81	5.35	1.74	77.06	58.37	46.58
CV	2.82	2.84	2.28	4.29	3.65	3.79

In tomato crop the highest seed germination was observed from 1:8 dilution to 1:10 dilution (spentwash:water) and poor or no germination was noticed in the rest of the treatments (Table 2). In tomato crop the

germination percent has increased with decrease in the effluent concentration. Tomato seeds did not germinate when the higher concentration of spentwash was higher which may be because of low water absorption capacity of

the seeds due to osmotic imbalance. This resulted in retardation of seed germination by increased salinity and conductivity of the solutes. Moreover, availability of oxygen for germinating seeds was low due to the presence of organic and inorganic chemicals in the spent wash.

In cowpea, sunflower and tomato, significantly higher root length, shoot length (cm) and vigour index were observed with higher dilution of distillery spentwash (>1:5) than at lower dilution(<1:4) or undiluted spentwash (Fig 1, 2, Table 3). Decrease in the concentration of distillery spentwash increased the shoot length, root length and vigour index of crops. Zalawadia *et al.* (1996) also reported the inhibitory effects of distillery effluents on seed germination, seedling growth, fresh weight and dry weight in onion. In cowpea and sunflower crops, higher shoot length (8.61 cm, 6.66 cm), root length (3.40 cm and 3.94 cm) and vigour index (1201% and 1061%) values were recorded in the 1:5 dilution which was on par with 1:6 (8.40 cm and 6.48 cm), (3.24 cm and 3.60 cm) and (1164% and 1008%) and 1:7 dilutions (8.61 cm and 6.26), root length (2.72 cm and 3.13 cm) and vigour index (1079% and 939%), respectively and lower values were observed in the undiluted spentwash. But

in tomato crop, maximum values of shoot length (7.53cm) root length (4.54cm) and vigour index (1208%) were recorded in the 1:8 dilution which was on par with 1:9 (shoot length 7.23cm root length 4.10cm and vigour index 1134, respectively) dilution and in 1:10 dilution the shoot length (7.32 cm) root length (3.63 cm) and vigour index (10.95%) was recorded. The values were lower in the rest of treatments.

The retardation of root and shoot growth at higher concentrations might be due to the scarcity of oxygen in the medium which might have restricted the energy supply (Rath *et al.* 2013). Further they also opined that toxic pollutants present in the effluent, mainly affected the respiration of the root. Less oxygen and more carbon dioxide concentrations in the medium resulted in low aeration that retarded the growth of plants.

The above findings lead to the conclusion that lower concentration of treated effluent, positively influence the growth parameters like germination percent, speed of germination, shoot length, root length and vigour index of cowpea, sunflower and tomato crops than at higher concentrations.

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