

**STANDARDIZATION OF FERTIGATION SCHEDULING
IN SUGARCANE THROUGH SUBSURFACE DRIP
IRRIGATION**

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***Affectionately dedicated to
my beloved Parents, Brothers,
Sisters & Friends***

**DEPARTMENT OF AGRONOMY
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GKVK, BENGALURU-65**

CERTIFICATE

This is to certify that the thesis entitled “STANDARDIZATION OF FERTIGATION SCHEDULING IN SUGARCANE THROUGH SUBSURFACE DRIP IRRIGATION” submitted in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** in **AGRONOMY** to the University of Agricultural Sciences, Bengaluru, is a bonafide record for research work carried out by **Mr. PADMANABHAN, M.**, during the period of his study in this university under my guidance and supervision and this thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or any other similar titles.

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Bengaluru
June, 2016

(PADMANABHAN, M.)

**STANDARDIZATION OF FERTIGATION SCHEDULING IN SUGARCANE
THROUGH SUBSURFACE DRIP IRRIGATION**

PADMANABHAN, M.

THESIS ABSTRACT

The field investigation on fertigation duration and fertigation levels on growth, yield and quality parameters of sugarcane juice and jaggery was carried out during *kharif* 2014 and 2015 at ZARS, VC, farm Mandya. The experimental site soil was red sandy loam with neutral pH 6.92, low electrical conductivity 0.162 dSm^{-1} and organic carbon 0.46 per cent, medium available nitrogen (292.5 kg ha^{-1}), phosphorus (38.2 kg ha^{-1}) and potassium (178.3 kg ha^{-1}). The experiment consisting fifteen treatments combinations with five fertigation duration and three fertigation levels with one control, laid out in factorial RCBD and replicated thrice. Results revealed that fertigation upto 9.5 months recorded significantly higher plant (250 t ha^{-1}) and ratoon (224 t ha^{-1}) cane yield which was on par with fertigation upto 8.0 months plant (234 t ha^{-1}) and ratoon (212 t ha^{-1}) cane yield. Fertigation levels did not differ significantly however, interaction effect of fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher plant (255 t ha^{-1}) and ratoon (227 t ha^{-1}) cane yield and was on par with fertigation upto 9.5 months with 100 per cent RDF plant (249 t ha^{-1}) and ratoon (225 t ha^{-1}) cane yield and fertigation upto 9.5 months with 75 per cent RDF plant (246 t ha^{-1}) and ratoon (221 t ha^{-1}) cane yield. Soil application of 100 per cent RDF with surface irrigation recorded significantly lower plant (147 t ha^{-1}) and (139 t ha^{-1}) ratoon cane yield. Thus results clearly indicated that 25 per cent saving in RDF besides recording 75 per cent higher cane yield with net return plant ($\text{₹ } 435185 \text{ ha}^{-1}$) and ratoon ($\text{₹ } 405965 \text{ ha}^{-1}$) cane could be obtained through sub surface drip irrigation.

June, 2016

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ಕಬ್ಬಿನ ಬೆಳೆಯಲ್ಲಿ ಒಳಮೈ ಹನಿ ರಸಾವರಿ ವೇಳಾಪಟ್ಟಿ ಪ್ರಮಾಣೀಕರಿಸುವಿಕೆ

ಪದ್ಮನಾಭನ್, ಎಂ.

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ವಲಯ ಕೃಷಿ ಸಂಶೋಧನಾ ಕೇಂದ್ರ, ವಿ.ಸಿ.ಫಾರಂ, ಮಂಡ್ಯದಲ್ಲಿ ೨೦೧೪ ಮತ್ತು ೨೦೧೫ರ ಹಂಗಾಮಿನಲ್ಲಿ ಕಬ್ಬಿನ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ, ಕಬ್ಬಿನ ರಸ ಮತ್ತು ಬೆಲ್ಲದ ಗುಣಮಟ್ಟದ ಮೇಲೆ ರಸಾವರಿ ಮತ್ತು ಗೊಬ್ಬರದ ಪರಿಣಾಮ ಅವಲೋಕಿಸಲು ಕ್ಷೇತ್ರ ಪ್ರಯೋಗವನ್ನು ಕೆಂಪು ಮರಳು ಮಿಶ್ರಿತ ತಟಸ್ಥ ರಸಸಾರ (೬.೯೨), ಕಡಿಮೆ ವಿದ್ಯುತ್ ವಾಹಕತೆ (೦.೧೬ ಡಿ.ಎಸ್/ಎಂ) ಮತ್ತು ಸಾವಯವ ಇಂಗಾಲ (ಶೇ ೦.೪೬), ಮಧ್ಯಮ ಸಾರಜನಕ (೨೯೨.೫ ಕಿ.ಗ್ರಾಂ/ಹೆ.), ರಂಜಕ (೩೮.೨ ಕಿ.ಗ್ರಾಂ/ಹೆ.) ಮತ್ತು ಪೊಟ್ಯಾಷ್ (೧೭೮.೩ ಕಿ.ಗ್ರಾಂ/ಹೆ.) ಅಂಶವಿರುವ ಮಣ್ಣಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಈ ಕ್ಷೇತ್ರ ಪ್ರಯೋಗದಲ್ಲಿ ಐದು ರಸಾವರಿ ಮತ್ತು ಮೂರು ಗೊಬ್ಬರದ ಮಟ್ಟದ ಜೊತೆಗೆ ಒಂದು ತಡೆ ಉಪಚಾರವನ್ನೊಳಗೊಂಡ ಒಟ್ಟು ಹದಿನೈದು ಉಪಚಾರಗಳನ್ನು ಅಪವರ್ತನೀಯ ಯಾದೃಚ್ಛಿಕ ಸಂಪೂರ್ಣ ವಿಭಾಗ ವಿನ್ಯಾಸದಲ್ಲಿ ಮೂರು ಬಾರಿ ಪುನರಾವರ್ತನೆಗೊಳಿಸಲಾಗಿತ್ತು. ಸದರಿ ಪ್ರಯೋಗದಿಂದ ಕಂಡುಬಂದ ಫಲಿತಾಂಶಗಳೇನಂದರೆ; ರಸಾವರಿಯ ಮೂಲಕ ಒಂಭತ್ತು ತಿಂಗಳು ಎರಡು ವಾರಗಳ ತನಕ ರಸ ಗೊಬ್ಬರಗಳನ್ನು ಒಳಮೈ ಹನಿ ರಸಾವರಿಯಲ್ಲಿ ನೀಡಿದಾಗ ಕಬ್ಬಿನ ಮೂಲ (೨೫೦ ಟನ್/ಹೆ.) ಮತ್ತು ಕೂಳೆ (೨೨೪ ಟನ್/ಹೆ.) ಬೆಳೆಯ ಇಳುವರಿಯಲ್ಲಿ ಗಮನಾರ್ಹವಾಗಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ, ಜೊತೆಗೆ ಎಂಟು ತಿಂಗಳವರೆಗೆ ರಸ ಗೊಬ್ಬರಗಳನ್ನು ಒಳಮೈ ಹನಿ ರಸಾವರಿಯಲ್ಲಿ ನೀಡಿದಾಗ ಸರಿಸಮಾನ ಮೂಲ (೨೩೪ ಟನ್/ಹೆ.) ಮತ್ತು ಕೂಳೆ (೨೧೨ ಟನ್/ಹೆ.) ಬೆಳೆಯ ಇಳುವರಿಯನ್ನು ಕಾಣಬಹುದಾಗಿದೆ. ಮುಂದುವರೆದಂತೆ, ಕಬ್ಬಿನ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ ಹಾಗೂ ಕಬ್ಬಿನ ರಸ ಮತ್ತು ಬೆಲ್ಲದ ಗುಣಮಟ್ಟದ ಮೇಲೆ ರಸಾವರಿಯು ಗಣನೀಯ ಪರಿಣಾಮ ಬೀರಿರುವುದಿಲ್ಲ. ಆದಾಗ್ಯೂ ರಸಾವರಿ ಅವಧಿ ಮತ್ತು ಗೊಬ್ಬರ ರಸಾವರಿಯ ಉಪಚಾರಗಳು ಪರಸ್ಪರ ಪ್ರತಿಕ್ರಿಯಿಸಿದ್ದು ಒಂಭತ್ತು ತಿಂಗಳು ಎರಡು ವಾರಗಳ ತನಕ ರಸ ಗೊಬ್ಬರಗಳನ್ನು ಒಳಮೈ ಹನಿ ರಸಾವರಿಯ ಜೊತೆಗೆ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶೇ.೧೨೫ರಷ್ಟು ರಸಗೊಬ್ಬರ ನೀಡಿದಾಗ ಗಮನಾರ್ಹವಾಗಿ ಮೂಲ (೨೫೫ ಟನ್/ಹೆ.) ಮತ್ತು ಕೂಳೆ (೨೨೭ ಟನ್/ಹೆ.) ಬೆಳೆ ಇಳುವರಿ ಹೆಚ್ಚಾಗಿರುವುದು ಕಾಣಬಹುದಾಗಿದ್ದು ಸದರಿ ಉಪಚಾರವು ರಸಾವರಿಯ ಮೂಲಕ ಒಂಭತ್ತು ತಿಂಗಳು ಎರಡು ವಾರದ ತನಕ ಶೇ.೧೦೦ ರಷ್ಟು ಶಿಫಾರಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರದ ಪ್ರಮಾಣ (ಮೂಲ ಬೆಳೆ - ೨೪೯ ಟನ್/ಹೆ. ಮತ್ತು ಕೂಳೆ ಬೆಳೆ - ೨೨೫ ಟನ್/ಹೆ.) ಮತ್ತು ಒಂಭತ್ತು ತಿಂಗಳು ಎರಡು ವಾರದ ತನಕ ಶೇ.೭೫ ರಷ್ಟು ಶಿಫಾರಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರದ ಪ್ರಮಾಣ (ಮೂಲ ಬೆಳೆ - ೨೪೬ ಟನ್/ಹೆ. ಮತ್ತು ಕೂಳೆ ಕಬ್ಬಿನ ೨೨೧ ಟನ್/ಹೆ.) ಇಳುವರಿ ಸರಿಸಮಾನಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ ಇದಲ್ಲದೆ, ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶೇ.೧೦೦ ರಷ್ಟು ರಸಗೊಬ್ಬರವನ್ನು ಮೇಲ್ಮೈ ನೀರಾವರಿ ಪದ್ಧತಿಯಲ್ಲಿ ಮಣ್ಣಿಗೆ ಉಪಚರಿಸಿದಾಗ ಗಣನೀಯವಾಗಿ ಮೂಲ ಬೆಳೆ (೧೪೭ ಟನ್/ಹೆ.) ಮತ್ತು ಕೂಳೆ ಕಬ್ಬಿನ (೧೩೯ ಟನ್/ಹೆ.) ಬೆಳೆಯ ಇಳುವರಿ ಕಡಿಮೆಯಾಗಿರುವುದು ಕಂಡುಬಂದಿದೆ. ಆದುದರಿಂದ ಶೇ.೨೫ ರಷ್ಟು ಶಿಫಾರಸು ಮಾಡಿದ ರಸಗೊಬ್ಬರದ ಉಳಿತಾಯ ಮಾಡುವುದರ ಜೊತೆಗೆ ೭೫ ರಷ್ಟು ಹೆಚ್ಚಿನ ಇಳುವರಿ ಮತ್ತು ನಿವ್ವಳ ಆದಾಯ (ಮೂಲ ಬೆಳೆ - ₹ ೪,೩೫,೧೮೫ /ಹೆ. ಮತ್ತು ಕೂಳೆ ಬೆಳೆ - ₹ ೪,೦೫,೯೬೫ /ಹೆ.) ಆದಾಯವನ್ನು ಒಳಮೈ ಹನಿ ರಸಾವರಿ ಪದ್ಧತಿಯಲ್ಲಿ ಪಡೆಯಬಹುದಾಗಿದೆ ಎಂದು ತಿಳಿದುಬಂದಿದೆ.

ಜೂನ್, ೨೦೧೬

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(ನಾಗರಾಜು)

ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

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LIST OF ABBREVIATIONS

Abbreviation	Expansion
DAP	Days after planting
S.Em	Standard error mean
C.D	Critical difference
B:C ratio	Benefit to cost ratio
NS	Non significant
N	Nitrogen
P, P ₂ O ₅	Phosphorus
K, K ₂ O	Potassium
kg ha ⁻¹	Kilogram per hectare
t ha ⁻¹	Tonnes per hectare
°C	Degree Celsius
cm	Centimetre
Ds m ⁻¹	Desi Simons per metre
p=0.05	At 5 per cent probability
<i>Viz</i>	Namely
%	Per cent
ZARS	Zonal Agricultural Research Station
RH	Relative humidity
RDF	Recommended dose of fertilizer
Cfu	Colony forming units
₹	Rupees
m	Metre
DAP	Days after planting
CCS	Commercial cane sugar

NMC	Number of millable canes
SSDI	Sub surface drip irrigation
SDI	Surface drip irrigation
WUE	Water use efficiency
Mg ha ⁻¹	Mega gram per hectare

I INTRODUCTION

Sugarcane is (*Saccharum officinarum* L.) globally cultivated in 115 countries for sugar production. The area under cultivation is 24.5 m ha with an annual production of 1850 m t and average productivity of 75.5 t ha⁻¹ (FAO, 2015). Sugarcane contributes ¾ of the total sugar production of the world remaining sugar is derived from sugarbeet (Anon., 2015). Sugarbeet cultivation and processing is highly subsidized in the European Union, which contributes nearly 21.5 per cent of world sugar. With the WTO agreement in place, sugarbeet cultivation may not remain a profitable proposition in European Union due to drastic reduction in subsidies on its production and processing. In this situation, the shortfall in sugar may be compensated by sugarcane producing countries like Brazil, India, China, Pakistan, USA, Australia, Thailand, Philippines, *etc* (Anon., 2015).

Sugarcane is an important commercial crop in India, provides sugar, jaggery, bio-fuel and manure besides many other by products and grown in two distinct agro-climatic regions. Tropical, largely comprising of Maharashtra, Karnataka, Gujarat and Tamil Nadu and Sub-tropical, region which includes Uttar Pradesh, Punjab, Haryana and Bihar. India is the world's second largest producer of sugarcane in terms of area, 5.3 m ha and production, 366 m t with productivity of 69 t ha⁻¹ contributing 19.98 per cent to world's total sugar production. In Karnataka, sugarcane is cultivated in an area of 0.50 m ha with a production of 47 m t with an average productivity of 94.0 t ha⁻¹ (Anon., 2015).

Higher doses of N coupled with lower levels of P and K fertilization in many sugarcane growing areas has resulted in poor quality of juice and soil degradation which is one of the main reasons for declining yield and low sugar recovery of Indian sugarcane (Sonawane and Sabale, 2000). Efficient use of N fertilizer is therefore important for economical crop production and also for ground and surface water quality. Insufficient N levels reduce profit and yield, while excessive N can pollute both surface and ground water. The excessive N also makes the plants susceptible to lodging and diseases, resulting in decreased yield besides increase input cost. Furthermore, large field to field variability of soil N supply restricts efficient use of N fertilizer when broad-based blanket fertilizer N recommendations are used (Cassman *et al.*, 1996). When N application is not synchronized with crop demand, N losses from the soil-plant system are largely leading to low N fertilizer use efficiency. Therefore effective management of fertilizer, particularly N is a major challenge for researchers and producers.

Traditional system of flood irrigation often results in leaching of mobile nutrients which in turn leads to pollution of water bodies and deterioration of soil health. Under drip irrigation such losses are minimized leading to higher yield of 25 to 30 per cent over conventional irrigation method. The maintenance of nutrients at optimum levels within the rhizosphere of plants is the primary factor governing efficient use of fertilizers when applied through subsurface drip irrigation system (Shukla *et al.*, 2009). The higher installation cost of drip irrigation system, which is a major deterrent in adoption of drip system could be reduced by manipulating lateral spacing and shifting to paired-row planting pattern, time and amount of

water/fertilizer application and higher planting densities within the cane furrows (Goel *et al.*, 2005).

Sugarcane production system presumed that by 2020 would undergo marked changes due to scarcity of water, land and labour, higher cost of inputs, vigorous competitions from other crops, enterprises and the price scenario of sugar in the international market. Adoption of modern frontier technologies would become necessary to overcome many of the problems faced by sugarcane farmers. Under the circumstances, the technologies namely sub surface drip irrigation and fertigation will have to be put to use on farm level for enhancing production with improved water and nutrient use efficiency by monitoring crop condition and assessment of crop acreage and production. Sugarcane being a long duration crop, requires relatively a large amount of irrigation water compared to other crops, which ranges from 1400 to 3000 mm ha⁻¹ depending on crop yield and climate.

Sugarcane being a giant crop producing huge amount of biomass, generally demands higher amounts of nutrients. A large number of research experiments have clearly demonstrated that for producing higher cane and sugar yield on a sustainable basis, application of adequate amounts of nutrients such as N, P and K is essential (Chaudhari *et al.*, 2000) besides secondary and micronutrients depends on the availability in the soil.

Mean while, the cost of chemical fertilizers have increased and there is a need for improving fertilizer use efficiency to derive more benefits. The best answer to this challenge is "Fertigation scheduling". Fertigation scheduling is the amount of fertilizer to be applied at any point of time so that, before the next fertigation, the plant has been able to assimilate a sufficient quantity of the nutrient. Here both water and fertilizers are delivered to crop simultaneously through a drip irrigation system. This approach reduces nutrient losses, mainly the N, due to leaching and as a result, fertilizer recovery or use efficiency is relatively higher. The amount of fertilizers lost through leaching can be as low as 10 per cent in fertigation. In the traditional system, 50 per cent loss is quite typical. Further, the ratios of fertilizers can be adjusted easily through the drip system. Fertigation scheduling ensures that essential nutrients are supplied precisely at the area of most intensive root activity according to the specific requirements of sugarcane crop and type of soil resulting in higher cane yields and sugar recovery (Bangar and Chaudhari, 2001).

Sugarcane crop in the economy of India has proved to be of vital importance. Thus, for its sustained yield levels over years, the key factors being water and nutrient management issues which need to be addressed in relation to climatic parameters. An average sugarcane crop takes up nearly 208 kg N, 53 kg P, 280 kg K, 6.3 kg Fe, 1.2 kg Mn, 0.6 kg Zn and 0.2 kg Cu from soil which can produce 100 t ha⁻¹ of sugarcane (Malavolta, 1994). This indicates that higher amounts of nitrogen and potassium need to be applied. These nutrients being most mobile in nature, subjected to various losses upon their application to soil. The rising cost of plant nutrients, and scarcity of water necessitate judicious use of nutrients and water through new technological options. The options are wider/paired row, planting method, drip fertigation and split application of nutrients as per crop demand/growth stage.

In this context, an experiment entitled “Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation” was planned at Zonal Agriculture Research Station, VC farm, Mandya, UAS, Bengaluru with the following objectives.

1. To study the effect of fertigation duration and levels on growth and yield of sugarcane under sub surface drip irrigation.
2. To asses the quality of sugarcane juice and jaggery as influenced by subsurface drip fertigation duration and levels.
3. To work out the nutrient use efficiency, water productivity and economics of sugarcane as influenced by fertigation duration and levels.

II REVIEW OF LITERATURE

Field experiment on “Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation” in plant and ratoon cane was conducted during 2014 and 2015 at Zonal Agriculture Research Station, VC farm Mandya, UAS, Bengaluru. The relevant research information available in sugarcane drip fertigation are reviewed and presented under separate headings in this chapter.

1. Importance of subsurface drip irrigation
2. Effect of subsurface drip irrigation on growth and yield of sugarcane.
3. Effect of fertilizer levels on growth and yield of sugarcane.
4. Effect of fertigation scheduling on growth and yield of sugarcane.
5. Impact of fertigation scheduling and levels on quality of sugarcane juice and jaggery.
6. Impact of fertigation on nutrient use efficiency.
7. Impact of drip irrigation and fertigation on water productivity.
8. Economic viability of drip fertigation.

2.1 Importance of subsurface drip irrigation (SDI)

Agriculture sector is one of the largest consumer of water. The overall efficiency of the flood irrigation system ranges between 25 and 40 per cent. Adoption of subsurface drip irrigation may help in saving significant amount of water and increase the quality and quantity of the produce. All this emphasizes the need for water conservation and improvement in water-use efficiency to achieve ‘more crop per drop’.

Application of water with integral drip lines at predetermined depth in the soil depending upon the soil type and crop water requirements. The development of improved plastic materials (thin walled drip tapes) has made subsurface drip irrigation system less costly and adoptable for many crops like cotton, maize and sugarcane (Smith *et al.*, 1991).

Subsurface drip irrigation has evolved into an irrigation method with high potential for efficient and economical productivity and its use has progressed from being a novelty employed by researchers to an accepted method of irrigation for both perennial and annual crops (Ayars *et al.*, 1999).

According to Ruskin (2000) the water can be applied in small and frequent amount to the medium and heavy textured soils since the water movement in the above soil is mainly due to capillary forces. So higher water saving can be achieved

with the same available water resources under subsurface drip irrigation (SDI). Subsurface drip irrigation system is a new method of irrigation in India. It is used to provide water to a substantial portion of the plant root system while maintaining a relatively dry soil surface (Bartolo, 2005).

Payero *et al.* (2005) mentioned the energy savings with SDI due to smaller pump requirements for relatively low pressure and small flow rates. In addition, SSDI restricts root rot and other soil diseases. It prevents crust creation that inhibits soil aeration and rainwater infiltration into the soil resulting in excessive surface run-off. Except the above, a subsurface irrigation system is not exposed to sun and extreme weather conditions that means longer material life. The permanent installation below the plough depth provides labour savings otherwise the cost of which is quite high in developed countries (Kalfountzos *et al.*, 2007).

These reviews indicated that there is a need for subsurface drip irrigation in sugarcane through which we can reduce the wastage of water to negligible amount.

2.2 Effect of subsurface drip irrigation on growth and yield of sugarcane.

Parikh *et al.* (1996) reported that higher cane (185 t ha^{-1}) and sugar yield (17.2 t ha^{-1}) was observed under subsurface drip irrigation. Dineshkumar and Hunsigi (1997) opined that yield attributes like cane length (3.2 m), cane diameter (3.4 cm) and single cane weight (1.88 kg) were increased through subsurface drip irrigation. Compared to surface irrigation yield attributes like cane length (2.8 m), cane diameter (3.1 cm) and single cane weight (1.61 kg).

Fertigation of nitrogen significantly increased the cane yield over the conventional method of nitrogen application with surface irrigation and the yield increase was to the tune of 32 per cent through drip irrigation over surface irrigation 26 per cent (Selvaraj *et al.*, 1997). Kwong *et al.* (1999) reported that tiller density, leaf area and sugarcane yield (180 t ha^{-1}) under subsurface drip fertigation were inferior to those obtained with the standard practice of burying $120 \text{ kg N ha}^{-1} \text{ year}^{-1}$ along the cane rows recorded cane yield (155 t ha^{-1}).

Chaudhari *et al.* (2000) opined that sub surface drip irrigation system resulted into higher cane yield (153.35 t ha^{-1}) which was 9 per cent higher over to that of conventional method (141.76 t ha^{-1}). Application of water through subsurface drip gave significantly higher sugarcane yield (183 t ha^{-1}) and recorded higher growth and yield parameters over surface flood irrigation method (121 t ha^{-1}) (Vaishnava *et al.*, 2002).

Kansas State University's research on suitability of using subsurface drip irrigation has shown that it is a feasible technology for irrigating field crops like corn and sugarcane (Lamm *et al.*, 2005). Pires *et al.* (2005) reported that subsurface drip irrigation produced higher cane yield (170 t ha^{-1}) as compared to surface irrigation, with average values of 141.3 and 132.4 Mg ha^{-1} cane yield, respectively.

Gui-Fen Chen *et al.* (2008) revealed that treatment of subsurface drip irrigation promoted faster and earlier growth of sugarcane, increased number of

tillers, improved elongation and diameter of stalk at later growth stage and increased yield with 31.9 and 22.8 per cent compared to the conventional fertilization without drip irrigation. Mahesh (2009) reported that higher cane yield (174 t ha^{-1}) was obtained under subsurface drip irrigation in double side planting of sugarcane over the surface irrigation (135 t ha^{-1}). Sathayaraj (2010) reported that subsurface drip irrigation to ratoon cane from 15 to 210 DAR recorded significantly higher number of millable canes (156.7 thousands ha^{-1}), higher cane yield (248.6 t ha^{-1}) and sugar yield (27.0 t ha^{-1}). Whereas, surface irrigation recorded significantly lower number of millable canes (141.2 thousands ha^{-1}), higher cane yield (208.3 t ha^{-1}) and sugar yield (20.4 t ha^{-1}). Hemalatha (2012) observed that subsurface drip irrigation system recorded higher yield parameters such as single cane weight (1.63 kg), number of millable canes ($83,000$) and cane yield (143.8 t ha^{-1}) compared with surface flood irrigation recorded lower single cane weight (1.21 kg), number of millable canes ($67,500$) and cane yield (104.3 t ha^{-1}).

All these reviews indicated that sugarcane grown under subsurface drip irrigation recorded higher growth and yield parameters and there is further scope to increase sugarcane yield level.

2.3 Effect of fertilizer levels on growth and yield of sugarcane.

Bob Wiedenfeld and Juan Enciso (2000) revealed that four N application rates ($0, 60, 120,$ and 180 kg N ha^{-1}) and three fertilizer application methods (through-the-subsurface drip, sidedress, and knifed into the middle of the plant stool or ‘stool splitter’) were evaluated on sugarcane for four successive crops. Nitrogen application through the drip system resulted in linear increase in cane yield every year up to the highest rate applied of 180 kg N ha^{-1} , averaging 74 kg per kg N applied in the plant through second ratoon crops, and 192 kg per kg N applied in the third ratoon crop. Over the 4 years of study, N application through the drip system produced yield which were significantly different from the side dress application, while the ‘stool splitter’ application method was consistently the most inefficient N fertilizer application method.

Raskar and Bhoi (2001) observed that maximum cane yield improvement with 125 per cent fertilizer level (157.19 and 17.35 t ha^{-1} cane and CCS yield, respectively). However, the yield obtained due to application of 75 and 100 per cent recommended dose of water soluble fertilizer through sub surface drip was on par, indicating 25 per cent savings in fertilizer. Among the various sources, yield of water soluble fertilizer (145.73 t ha^{-1}) was at par with the yield obtained by fertigation of urea, diammonium phosphate and muriate of potash.

Karthikeyan *et al.* (2003) revealed that higher number of millable canes ($87,500 \text{ ha}^{-1}$) was recorded with split application of K ($168.75 \text{ kg ha}^{-1}$) along with recommended dose of N (225 kg ha^{-1}) and P (62.5 kg ha^{-1}) through drip fertigation. Whereas, surface flood irrigation recorded lower number of millable canes ($78,160 \text{ ha}^{-1}$).

Mahendran and Dhanalakshmi (2003) observed higher cane and sugar yield (181.6 and 26.14 t ha^{-1} , respectively) with 120 cm spaced sugarcane under sub surface

drip irrigation at 100 per cent RDF through fertigation. Conventional surface method of furrow irrigation recorded lower cane and sugar yield (168.3 and 18.4 t ha⁻¹, respectively). Patel (2004) observed that under fertigation the millable cane yield was not altered significantly by either level (50, 75 and 100 per cent) or frequency (Weekly, fortnightly and monthly) of fertigation application. This revealed that, application of 50 per cent RDF would produce identical yield.

Mahadkar *et al.* (2005) reported that the increase in fertilizer levels from 75 to 125 per cent of RDF to sugarcane increased cane yield, CCS yield, millable canes ha⁻¹, cane weight, number of internodes and girth of cane. Significantly higher cane and CCS yield (144.81 t ha⁻¹ and 15.69 t ha⁻¹, respectively) were recorded at 125 per cent RDF than with rest of fertilizer treatments and it produced 28.46 and 9.52 per cent increase in yield over 75 and 100 per cent RDF, respectively. Mahendran *et al.* (2006) opined that fertigation upto 150 per cent level of recommended dose of N and K in 14 equal splits up to 210 DAP to sugarcane crop resulted in higher cane yield of 173.5 t ha⁻¹. However, surface method of irrigation recorded lower cane yield of 147.4 t ha⁻¹.

Raul *et al.* (2008) observed that irrigation system together with the application of N-fertilizer at 140 kg ha⁻¹ through drip irrigation recorded significant differences in dry matter accumulation of shoots, and for the production of stalks and sugar, respectively 94, 105 and 106 per cent, higher when compared to the not irrigated, without N-fertilizer. There was a positive and synergistic effect of irrigation with N-fertilizer on the productivity of stalks and sugar. Ratoon sugarcane irrigated with subsurface drip had the highest yield (22 Mg ha⁻¹ of sugar) with the dosage of 140 kg N ha⁻¹.

Shukla *et al.* (2009) reported that potassium (K) fertigation in sugarcane increased the number of buds per stubble, number of stalks, dry matter accumulation, number of millable canes and individual cane weight in ratoon cane. Potassium content of stubble increased by 16.7 per cent with K fertigation. The content of reducing sugars in buds at the time of ratoon initiation improved significantly with K fertigation. Ratoon cane yield increased by 15.21 per cent (74.1 t ha⁻¹) while sugar yield increased by 13.9 per cent (8.2 t ha⁻¹) as compared with control with K fertigation.

Nadagouda (2011) opined that 125 per cent RDF under sub surface drip irrigated plant cane recorded significantly superior yield (146.7 t ha⁻¹) over furrow irrigated plots (124.0 t ha⁻¹) with higher cane height (2.45 m), cane weight(1.79 kg), cane girth (3.13 cm) and population of millable canes (115340 ha⁻¹). Gouri *et al.*, (2012) observed that application of 150 per cent recommended dose of N & K fertilizers applied in the form of urea and muriate of potash through drip fertigation is the best alternative to using expensive water soluble and liquid fertilizers and recorded higher number of millable canes (87,401ha⁻¹) and cane yield (106.9 t ha⁻¹). However, conventional method of furrow irrigation recorded lower cane yield (89.6 t ha⁻¹).

Guruswamy (2013) opined that yield attributes like number of millable canes m⁻¹ (28.4), individual cane weight (2.12 kg), cane yield (193.6 t ha⁻¹) and sugar yield (18.91 t ha⁻¹) with fertigation of 125 per cent recommended dose of P & K (50 per

cent P and K as basal, balance nutrients through WSF) were favorably influenced by subsurface drip fertigation treatments. However, surface method of irrigation recorded lower cane yield (170.3 t ha⁻¹) and sugar yield (16.34 t ha⁻¹).

Sandhu *et al.* (2013) observed that maximum cane and sugar yield with split application of N at weekly interval, through subsurface drip irrigation resulted in 25 per cent increase in yield and 44.9 per cent water saving as compared to soil application of recommended NPK. Deshmuke (2014) stated that subsurface drip at 150 per cent RDF recorded highest cane weight (1.78 kg) and cane yield (185 t ha⁻¹) compared to surface irrigation (1.52 kg cane weight and 120 t ha⁻¹ cane yield).

Pawar *et al.* (2014) opined that drip irrigation resulted into 25 per cent increase in sugarcane yield whereas drip with fertigation resulted into 42 per cent increase in yield as compared to conventional method. Application of water soluble fertilizers had positive effect on periodical availability of nutrients and uptake than conventional fertilizer. Dilip and Mandakini (2015) reported that diameter of the sugarcane (3.21 cm) was higher under drip irrigation of 125 per cent RDF than the diameter of cane produced under surface irrigation (2.9 cm).

Application of fertilizers through subsurface drip fertigation system can improve sugarcane growth and yield parameters by saving 25 per cent of applied fertilizer.

2.4 Effect of fertigation scheduling on growth and yield of sugarcane.

Dineshkumar and Hunsigi (1997) observed that split application of recommended nutrients through drip upto 210 DAP increased the cane and sugar yield (170 t ha⁻¹ and 15.4 t ha⁻¹) over furrow irrigation cane (151 t ha⁻¹) and sugar yield (13.9 t ha⁻¹). Bangar and Chaudhari (2001) reported that significantly higher cane yield (153.35 t ha⁻¹) with water-soluble N, P and K fertilizers in 20 equal weekly splits compared to straight fertilizers (141.76 t ha⁻¹) under sub surface drip irrigation, while conventional fertilizers with surface irrigation recorded the lowest yield (115.74 t ha⁻¹).

Bhoi *et al.* (2001) reported that under paired rows (75 cm), four rows (90 cm) and subsurface drip irrigation through N fertigation in 4, 10 and 20 splits recorded mean cane yield of 171.4 t ha⁻¹ and was found highest with four row planting with 20 splits. However, paired row planting with 20 splits of N produced similar yield of 169.9 t ha⁻¹. Deshmukhe *et al.* (2001) reported that millable cane length (2.3 m), girth (2.8 cm) and number of internodes (25.0) were higher under drip irrigation at weekly interval than furrow method of irrigation (1.9 m, 2.55 cm, 22.0, respectively).

Mohan (2002) observed that cane grown under subsurface drip irrigation upto 8 months recorded the cane yield of 125 t ha⁻¹ which was 92 per cent higher than the yield recorded under surface irrigation (65 t ha⁻¹). Increase in cane yield by 35.1 t ha⁻¹ was noticed with nitrogen through drip at 21 days interval as compared to the conventional method of fertilizer application with surface irrigation (Ridge and Hewson, 2002). Application of 80 per cent recommended dose of fertilizer in seven

splits through drip gave significantly higher sugarcane yield of 183 t ha⁻¹ over surface irrigation cane yield of 110 t ha⁻¹ (Vaishnava *et al.*, 2002).

Mahendran *et al.* (2006) opined that drip fertigation of RDF from 15 DAP to 210 DAP sugarcane under paired row method of sugarcane planting recorded the highest cane (190 t ha⁻¹) and sugar yield (17.8 t ha⁻¹). Drip fertigation with 125 per cent recommended dose of N and K fertilizer upto 240 DAP has registered higher dry matter production (DMP) followed by 100 per cent drip fertigation (Rajasekaran, 2007).

Dhotre *et al.* (2008) observed that irrigation at 10 days interval recorded higher cane yield of 134.9 t ha⁻¹ under subsurface drip irrigation compared to conventional method of cultivation (65 t ha⁻¹). Yadav *et al.* (2008) reported that subsurface drip irrigation with the application of 75 per cent recommended dose of N and K₂O in 9 equal splits at an interval of 20 days was found optimum for sugarcane which improved the quality of cane and the commercial cane sugar by 46.4, 35.8 and 15.1 per cent as a result of drip irrigation over that conventional flood irrigation treatment.

Chandrashekar (2009) revealed that fertigation fortnightly through drip recorded higher plant height (3.15 m), cane yield (195 t ha⁻¹), cane girth (3.2 cm), single cane weight (1.72 kg), leaf area index (4.72) and cane yield (153 t ha⁻¹). Whereas, surface flood irrigation recorded lower plant height (2.85 m), cane girth (2.7 cm), single cane weight (1.40 kg), leaf area index (4.22) and cane yield (153 t ha⁻¹). Mahesh (2009) found that subsurface drip fertigation upto 9 months with 120 cm lateral spacing as double side planting recorded the maximum cane yield of 180 t ha⁻¹ where as the lower cane yield of 96 t ha⁻¹ was recorded under surface irrigation with soil application of RDF.

The highest and economic cane yield could be obtained by applying 346.1 kg N, 141.9 kg P₂O₅ and 401.1 kg K₂O per ha, which could produce 102 t ha⁻¹ of cane under subsurface drip irrigation over conventional method of surface irrigation recorded lower cane yield of 88 t ha⁻¹ (Lin Xu *et al.*, 2010). Nadagouda (2011) reported that fertigation upto 125 per cent RDN and K fortnightly recorded higher plant height (2.85 m), cane yield (167 t ha⁻¹), cane girth (29.0 mm) and five cane weight (6.92 kg) over conventional method of flood irrigation recorded lower cane yield (103 t ha⁻¹), cane girth (22.0 mm) and five cane weight (5.89 kg).

Fertigation scheduling through subsurface drip irrigation helps to meet the nutrient demand of the crop through out the growth stages resulting in higher growth and yield parameters.

2.5 Impact of fertigation scheduling and levels on quality of sugarcane juice and jaggery

Application of 250 kg nitrogen through sub surface drip and 50 kg N through pressmud showed positive response with respect to brix, pol, CCS per cent and sugar yield (Sonawane and Sabale, 2000). The application of straight fertilizers (only N through drip) and urea, diammonium phosphate and muriate of potash were the best

alternate sources to water soluble fertilizers (19-19-19). Nevertheless, water-soluble fertilizers had greater influence on quality of jaggery (Bangar and Chaudhari, 2001).

Bhoi *et al.* (2001) noticed that improvement in quality of jaggery with increase in number of N splits, while increased fertilizer level had no significant influence on juice quality. Raskar and Bhoi (2001) reported that improvement in cane juice quality with increasing levels and number of splits of fertigation over soil application of fertilizer. More *et al.* (2005) observed that improvement in juice and jaggery quality with increase in fertilizer levels. The brix, purity and CCS per cent were significantly higher with application of 125 per cent RDF than with 75 per cent RDF. But the pol per cent was higher with the application of 100 per cent RDF.

Shinde *et al.* (2005) reported that improvement in juice quality due to fertigation treatments over conventional method. Juice analysis, however, indicated no significant differences in CCS per cent when nutridrip was supplied through sub surface drip irrigation (Deshmukh *et al.* 2006). Mahendran *et al.* (2006) reported that two row planting under drip irrigation with 100 per cent RDF had higher juice weight than the surface irrigation methods under all other methods of planting. It also registered higher brix (19.40 %), pol (17.26 %), purity (89.00 %) and CCS (12.30 %) compared to other treatments. Overlap planting with surface irrigation recorded lower brix (18.40 %), pol (16.26 %), purity (85.00 %) and CCS (10.80 %).

Venkatakrishnan and Ravichandran (2007) observed higher value of brix (20.32 %) and pol (19 %) with 100 per cent recommended dose of NPK as chemical fertilizer through sub surface drip and soil application of FYM at the rate of 10 t ha⁻¹. Gui-Fen Chen *et al.* (2008) revealed that subsurface drip fertigation with 125 per cent RDF had no influence on quality parameters *viz.*, brix (19.61 %), sucrose (15.23 %) and purity (93.06 %) compared to the conventional fertilization without drip irrigation and drip fertilization, respectively.

Andressa *et al.* (2009) opined that nitrogen supplied through subsurface drip fertigation in the form of urea (0, 50, 100, 150 and 200 kg N ha⁻¹). Variation in Brix (%), pol (%), juice (%), purity (%) and TRS of sugarcane and recorded significant reductions at 200 kg N ha⁻¹. However, stalk and sugar yield increased linearly with the increment in nitrogen doses applied through subsurface drip fertigation. Bakiyathu Saliha *et al.* (2009) reported higher quality parameters (brix, pol, purity and CCS per cent of 20.92, 18.88, 90.25 and 13.55, respectively) of sugarcane variety CO 86032 under subsurface drip fertigation over surface irrigation (brix, pol, purity and CCS per cent of 20.26, 17.31, 90.10 and 12.19, respectively).

Mahesh (2009) concluded higher brix (18.2%), pol (15.6%) and CCS (11.01 %) with subsurface drip irrigation at 100 per cent RDF when compared to surface irrigation, which recorded lower brix (17.4 %), pol (14.3%) and CCS (9.8 %). Prabhakar *et al.* (2009) revealed that application of 100 per cent recommended dose of nitrogen through subsurface drip fertigation was not influenced the quality parameters *viz.*, brix (17.47 %), sucrose (14.55 %), purity (82.86 %) and CCS (6.41 %) of sugarcane.

Gouri *et al.* (2012) opined that there was no significant difference in cane yield of sugarcane among different forms of fertilizers at higher doses of subsurface drip fertigation, i.e. at 150 per cent recommend dose of fertilizers. Juice quality in terms of sucrose and CCS per cent was not influenced significantly by different treatments. Hemalatha (2012) observed that application of N as urea fertilizer showed positive response up to 195.5 kg ha⁻¹ through subsurface drip irrigation and enhanced the quality parameters such as brix, sucrose, commercial cane sugar and purity per cent. Krishnaswamy (2013) opined that fertigation of 125 per cent recommended dose of N, P & K through subsurface drip recorded higher quality parameters of sugarcane brix (17.46 %) and commercial cane sugar (9.77 %) at harvest over surface irrigation brix (17.12 %) and commercial cane sugar (8.93 %).

Dharmarajan (2014) observed that the juice quality of sugarcane such as brix (18.2 %) and CCS (9.0 %) were significantly superior in subsurface drip irrigation with 100 per cent RDF as compared to other surface irrigation methods brix (16.7 %) and CCS (7.94 %) recorded lower values. Dunham (2014) reported that quality parameters such as pol (19.01 %), CCS (13.67 %), purity (96.37 %) and reducing sugars (3.38 %) were higher under 100 per cent RDF. Compared to surface irrigation pol (18.88 %), CCS (12.07 %), purity (95.27 %) and reducing sugars (3.02 %). While jaggery quality parameters such as higher sucrose (75.55%) and lower reducing sugars (12.45 %) were observed.

Giridharan and Muthukumaran (2014) observed that fertigation upto 8 months with 100 per cent RDF recorded higher jaggery recovery (10.09 %), jaggery yield (11.44 t ha⁻¹) and sucrose per cent in jaggery (86.45 %). Whereas, surface method of irrigation recorded lower jaggery recovery (9.59 %), jaggery yield (10.14 t ha⁻¹) and sucrose per cent in jaggery (85.9 %). Ghugare and Lokesh (2015) reported that there was sizable increase in jaggery yield (26 t ha⁻¹) under drip irrigation with fertigation level of 125 per cent RDF compared to surface irrigation (19 t ha⁻¹). Kittad (2015) observed higher sugar yield (25 t ha⁻¹) under sub surface drip irrigation as compared to conventional method (20 t ha⁻¹).

Overall results revealed that fertigation scheduling and levels on sugarcane juice quality parameters and jaggery was improved without any detrimental effect.

2.6 Impact of fertigation on nutrient use efficiency

Kumar *et al.* (2000) reported that fertigation of liquid fertilizers through drip irrigation resulted in fertilizer use efficiency of 48 per cent over conventional method of 35 per cent fertilizer use efficiency. Patel *et al.* (2001) observed that 25 per cent fertilizer saving and 20.74 per cent yield increase due to supply of liquid fertilizers through sub surface drip fertigation over surface irrigation 17.21 per cent yield increase.

Raskar and Bhoi (2001) reported that 20 to 30 per cent increase in cane yield and 42 to 52 per cent total water savings with drip irrigation. Higher water and fertilizer use efficiencies were also reported under drip irrigation at 50 per cent of recommended dose of fertilizers compared to surface irrigation. Alexander *et al.* (2002) observed that application of N @ 343 kg ha⁻¹ through subsurface drip irrigation

recorded the highest N content of cane (0.51 per cent). Whereas, soil application of N @ 343 kg ha⁻¹ recorded lowest N content of cane.

Thorburn *et al.* (2002) revealed that application of nitrogen through subsurface drip irrigation in sugarcane with equal splits at eight days interval saved 20 to 40 per cent nitrogen compared to furrow irrigation. Vaishnava *et al.* (2002) opined that subsurface drip fertigation recorded the highest cane yield (182.8 t ha⁻¹) and fertilizer use efficiency (476 kg cane kg⁻¹ fertilizer) were obtained when fertilizer application was 80 per cent of the maximum. The control treatment had the lowest fertilizer use efficiency of 343 kg kg⁻¹ fertilizer.

Weigel *et al.* (2002) stated that fertigated treatments at 96 kg N ha⁻¹ showing a yield increase of 12 per cent compared to the solid treatment at the same application rate, and an increase of 8 per cent compared to the solid treatment at 144 kg N ha⁻¹ suggesting an overall improvement in fertilizer N use efficiency of about 30 per cent. Prasad *et al.* (2003) indicated that nitrogen applied through drip appeared to favour fertilizer efficiency as compared to surface application. Uptake of fertilizer N by sugarcane was indeed improved by supplying urea daily through the drip irrigation network system. Although N fertilizer use efficiency was nearly doubled by fertigating the sugarcane daily over a 10-week period, the improvement in fertilizer use efficiency was, however, not accompanied by a correspondingly significant increase in cane or sugar yield.

Batta *et al.* (2005) reported that lower fertilizer-use efficiency of 25-35 per cent in surface irrigation while in subsurface drip fertigation, fertilizer use efficiency was upto 85 per cent in sugarcane. Whereas, surface irrigation recorded fertilizer use efficiency upto 70 per cent. Bhoi and More (2005) observed that drip fertigation in sugarcane resulted in higher nitrogen use efficiency (654.5 kg kg⁻¹ N), phosphorus use efficiency (2880.0 kg kg⁻¹ P₂O₅) and potassium use efficiency (1607.1 kg kg⁻¹ K₂O) as compared to surface irrigation (349.1 kg kg⁻¹ N, 1536.0 kg kg⁻¹ P₂O₅ and 857.1 kg kg⁻¹ K₂O).

Goel *et al.* (2005) reported that the N and K contents in the index leaf of sugarcane were higher in drip method compared to furrow method of irrigation. They attributed this to higher fertilizer use efficiency and maintenance of optimum nutrient concentration in soil solution under subsurface drip method of sugarcane cultivation. Meyer *et al.* (2007) observed that adoption of subsurface drip fertigation is an overall improvement in irrigated areas of about 28 per cent in N fertiliser use efficiency than conventional method of about 23 per cent.

Natarajan (2008) reported that application of moderately higher level of nitrogen (325 kg ha⁻¹) to sugarcane under drip irrigation recorded higher nitrogen use efficiency indicating the optimum level of N suitable to soil and climatic conditions. Spilt application of nutrients had positive influence on nutrient use efficiency, growth, yield and quality of sugarcane. Spilt application of N and K increased the tiller number with increase in nitrogen uptake (Geddaway and Debaby, 2009).

Shukla *et al.* (2009) reported that potassium fertigation to standing plant cane increased the number of buds per stubble and number of stalks in ratoon cane. K

content of stubble increased by 16.7 per cent with K fertigation. Besides, K fertigation improved dry matter accumulation, number of millable canes, individual cane weight, ratoon cane yield by 15.21 per cent (74.1 t ha^{-1}) and sugar yield by 13.9 per cent (8.2 t ha^{-1}) than soil application of recommended NPK cane yield by 11.71 per cent (51.3 t ha^{-1}) and sugar yield by 12.66 per cent (6.9 t ha^{-1}).

Results indicate that fertigation through subsurface drip irrigation in sugarcane helps in efficient utilization of applied nutrients as a result the nutrient use efficiency is relatively higher when compared to conventional method of nutrient management.

2.7 Impact of drip irrigation and fertigation on water productivity

Sugarcane cultivation through subsurface drip recorded $1530 \text{ kg cane ha cm}^{-1}$ of water, whereas it was only $690 \text{ kg ha-cm}^{-1}$ under surface irrigation (Selvaraj *et al.*, 1997). Application of fertilizer through drip resulted in significant increase in cane yield (28 %) over surface irrigation method (21 %) (Bangar and Chaudhari, 2001). Hapase *et al.* (2002) reported that 50-55 per cent water saving in daily drip irrigation with 12-37 per cent increase in yield and 2.7 times higher water use efficiency compared to conventional furrow irrigation.

Vaishnava *et al.* (2002) revealed that highest mean cane yield (180.0 t ha^{-1}) was obtained under seasonal application of 1955 mm irrigation water by subsurface drip fertigation. The control treatment flood irrigation received a total of 2466 mm irrigation water and the yield was 86.9 t ha^{-1} . Accordingly, the water use efficiency (WUE) was 92.0 and $35.2 \text{ kg ha}^{-1}\text{mm}^{-1}$, respectively. Chavai *et al.* (2003) reported that saving in water ranging from 20 to 60 per cent, in labour and fertilizer, reduction in weed intensity and increase in sugarcane yield under subsurface drip fertigation. Fertigation through drip attributed 24.34 per cent increase in yield with 46.52 per cent water saving as compared with recommended fertilizer applied with surface irrigation (106.48 t ha^{-1}). All quality parameters did not differ significantly due to fertigation up to 240 DAP in CoC-671 (Rajanna and Patil, 2003).

Shinde *et al.* (2003) observed that automatically controlled drip irrigation used 56 per cent less water compared with conventional irrigation, increased yield by 52 per cent, and increased water use efficiency by 2.5 to 3 fold. Singandhupe *et al.* (2003) revealed that subsurface drip irrigation at two, three, and four days interval produced 20, 16 and 13 per cent higher cane yield than furrow irrigation in which the cane yield was 131.4 t ha^{-1} . During the crop growth period, soil moisture depletion was 34–46 per cent in furrow-irrigated treatment and 5–20 per cent in drip-irrigated treatment. Similarly, 108 per cent higher irrigation water use efficiency was achieved in 2-day drip irrigation over furrow irrigation in which the irrigation water efficiency was $787 \text{ kg ha}^{-1} \text{ cm}$.

Colaizzi *et al.* (2004) reported that higher yield and WUE were observed under subsurface drip irrigation when compared to surface method of irrigation. More and Bhoi (2004) reported higher cane yield with wide-spaced paired row planting at 75-150 and 90-180 cm recorded higher cane yield with 54.50 and 54.24% saving in irrigation water over 100 cm spaced normal planting. Narayanamoorthy (2004)

reported that 23 per cent higher yield, 44 per cent water saving and 1059 kwh ha⁻¹ electricity saving by using drip irrigation in comparison with flood method of irrigation for sugarcane reported 18 per cent increase in yield with 36 per cent water saving. Siroda *et al.* (2004) stated that adoption of subsurface drip irrigation in sugarcane increased the cane yield up to 170 t ha⁻¹ with higher WUE of 10.31 kg m⁻³.

Water use efficiency of cane increased by 26 per cent in subsurface drip irrigation system when same quantity of water and N fertilizer was applied as compared to surface irrigation (Aujla *et al.*, 2005). The water use efficiency ranged from 1.017 to 1.403 t ha cm⁻¹ in drip irrigation compared to 0.48 to 0.60 t ha cm⁻¹ in surface method (Dhindwal *et al.*, 2005). Evett *et al.* (2005) concluded that subsurface drip irrigation (SSDI) systems reduced evaporation losses compared to surface drip irrigation. The cane yield and number of millable cane in plant and ratoon crop were higher in drip irrigation and the sugar yield also followed the same trend as cane yield (Goel, *et al.*, 2005).

Khalid *et al.* (2005) reported that SDI helped to save water from 11-18 per cent over flood irrigation system that had no significant contribution in net benefits. Lamm *et al.* (2005) revealed that low water requirement and higher water saving were observed under subsurface drip in sugarcane. In conventional overhead sprinkler irrigation it was recorded 1300 mm ha⁻¹ and with subsurface drip it was only 300 mm ha⁻¹. Mahadkar *et al.* (2005) observed that 30.62 per cent saving in water under drip over surface irrigation. The quantity of water applied through drip was 128.92 ha-cm as against 248.29 ha-cm in conventional surface irrigation method resulting in 48.07 per cent water saving.

Magar and Lamm (2005) reported that water saving under drip irrigation was 64 per cent and increased cane yield of about 22 per cent compared to surface irrigation. The three years average water use efficiency under drip irrigation system at 100 per cent RDF (0.989 t ha-cm⁻¹) was 87.31 per cent higher compared to surface irrigated cane (More *et al.* 2005). Narayanamoorthy (2005) showed that cane productivity gains of 54 per cent and water saving of 58 per cent due to drip irrigation as compared to flood irrigation gains of 41 per cent cane productivity. Deshmukh *et al.* (2006) opined that 70 per cent of recommended dose of urea + 85 per cent recommended dose of KCl in 13 equal splits through subsurface drip irrigation + recommended dose of SSP in two splits by soil application resulted in higher water use efficiency more than doubled with the use of the drip system, from 5.4 to 12.1 kg cane m⁻³ with a cane yield of 175.50 t ha⁻¹.

Mahendran *et al.* (2006) stated that drip irrigation to cane crop in paired row planting registered the WUE of 85 per cent with the cane yield of 205 t ha⁻¹ whereas surface method of irrigation recorded cane yield of 167 t ha⁻¹. Ndeketeya *et al.* (2007) observed that a significant difference in sugar-cane fresh weight and sucrose content between drip and furrow treatments. Drip had a higher fresh weight value of 134.5 t ha⁻¹ compared to 110.95 t ha⁻¹ for furrow systems. Wei *et al.* (2008) reported that distribution of rainfall in spring, autumn and winter did not satisfy the water requirement of sugarcane, as it provided only 74, 4, 68, 6 and 35.7 per cent of the water requirement of sugarcane at the seedling, tillering and maturity stages, respectively. Fertigation enhanced sugarcane fertilizer and water use efficiency.

Esther Shekinah *et al.* (2009) opined that water saving of 40 per cent in the plant crop of sugarcane and 52 per cent in the ratoon was brought about by subsurface drip fertigation. Mahesh (2009) revealed that subsurface drip fertigation to cane crop registered significantly higher WUE ($152 \text{ kg ha}^{-1} \text{ mm}^{-1}$) as compared to surface irrigation with soil application of recommended dose of fertilizers ($56.02 \text{ kg ha}^{-1} \text{ mm}^{-1}$). Gouthaman (2010) reported that subsurface drip irrigation significantly increased the tiller production ($210.6 \text{ thousands ha}^{-1}$) as compared to surface method ($157.3 \text{ thousands ha}^{-1}$). Subsurface drip irrigation registered significantly higher number of millable cane (139.5 and $157.2 \text{ thousands ha}^{-1}$), cane length (3.66 and 3.59 m), individual cane weight (1.73 kg and 1.56 kg), number of internodes per cane (26.7 and 26.4), internode length (15.5 and 15.3 cm) and cane girth (3.19 and 2.97 cm) in plant and ratoon crop, respectively. Whereas, soil application of 100 per cent RDF through surface irrigation recorded lower number of millable cane (127.3 and $144.92 \text{ thousands ha}^{-1}$), cane length (3.26 and 3.04 m), individual cane weight (1.40 kg and 1.36 kg), number of internodes per cane (24.2 and 24.6), internode length (15.1 and 15.0 cm) and cane girth (2.93 and 2.87 cm) in plant and ratoon crop, respectively (Sathyaraj, 2010).

Veeraputhiran *et al.* (2011) observed that water use efficiency of subsurface drip fertigation to sugarcane was $65.8 \text{ kg ha}^{-1} \text{ mm}^{-1}$ while it was only $35.6 \text{ kg ha}^{-1} \text{ mm}^{-1}$ under conventional method of sugarcane cultivation. Dilip and Mandakini (2015) reported that cane grown under subsurface drip irrigation resulted in 75 per cent saving of water and recorded the cane yield of 125 t ha^{-1} which was 52 per cent higher than the yield recorded under surface irrigation (65 t ha^{-1}).

The above reviews conclude that irrigation through subsurface drip resulted in higher sugarcane yield with higher water use efficiency as compared to surface method of irrigation in sugarcane cultivation.

2.8 Economic viability of drip fertigation.

Drip irrigation along with 225 kg N ha^{-1} and surface irrigation with 175 kg N ha^{-1} recorded a total net income of ₹. $60,000 \text{ ha}^{-1}$ and ₹. $53,000 \text{ ha}^{-1}$, respectively. For every rupee investment there was a return of ₹. 2.22 to 2.37 under the drip system compared to 2.03 under surface irrigation (Selvaraj *et al.*, 1997). Berad *et al.* (1998) reported that application of only N (urea) through drip registered 15 per cent higher yield (68.5 t ha^{-1}) and 7 per cent higher net returns (₹. $1,09,130 \text{ ha}^{-1}$) compared to surface irrigation with same fertilizer dose. But, high cost of liquid fertilizers (about 3.5 times) over solid fertilizers significantly reduced their economic viability substantially. Fertigation of liquid fertilizers through drip resulted in 25 per cent saving in fertilizer and 20.74 per cent increase in yield. However, the high cost of liquid fertilizers significantly reduced the net profit and B:C ratio.

Balasubramanian (2001) compared economics of fertigation in India over farmer's practice (conventional fertilizers) in terms of yield, quality and monetary returns. He observed that weekly fertigation was more convenient and economically profitable for the farmers. Bangar and Chaudhari (2001) reported that maximum net seasonal income with water soluble fertilizers when compared to straight fertilizers (₹. $64,347 \text{ ha}^{-1}$ and ₹. $61,400 \text{ ha}^{-1}$, respectively). Higher B:C ratio was observed with

water soluble fertilizers than followed by straight fertilizers (1.18 and 1.12, respectively).

The supply of water soluble fertilizers was marginally beneficial in terms of net seasonal returns (₹. 62,407 ha⁻¹) when compared to conventional fertilizers (₹. 61,520 ha⁻¹) with B:C ratio of 1.18 and 1.01 for conventional fertilizer and water soluble fertilizers, respectively (Bhoi *et al.* 2001).

Shinde *et al.* (2003) observed that lower net returns and B:C ratio with all liquid fertilizer levels as against only N (urea) fertigation (₹. 52,423 ha⁻¹ and 1.90, respectively) due to higher cost of liquid fertilizers. More and Bhoi (2004) observed that net profit cm⁻¹ of water in paired row planting of 75-150 and 90-180 cm were ₹. 676.53 and ₹. 752.63 with B:C ratio of 2.09 and 2.18, respectively, which were higher than 100x30 cm normal planting (₹. 284.05 net profit and 2.31 B:C ratio) and 90x30 cm 4 row planting (₹. 526.32 net profit cm⁻¹ and 1.38 B:C ratio).

Kasar and shinde (2005) revealed that the cropping and irrigation intensity were higher by 20.65 and 24.68 per cent, respectively on drip adopted farms. The per hectare investment cost on drip irrigation system for sugarcane crop was ₹. 46,467. The per hectare saving in human labour and electric motor power on drip farms was 87.07 man days and 130.37 hours, respectively. The saving in water use and electricity consumption was 28 per cent more on drip farms. The drip irrigation system showed increased productivity by 27.65 per cent, and net return by ₹. 20, 234 ha⁻¹.

Mahadkar *et al.* (2005) registered higher net income of ₹. 77,505 ha⁻¹ and B:C ratio of 1.97 under fertigation with two row planting system. Though, the surface irrigation under three row planting system registered equal B:C ratio of 1.93, the net return was very low compared to the fertigation treatments. The results also clearly indicated that, drip fertigation is economically viable at all levels and method of planting compared to surface irrigation method.

Mahendran *et al.* (2005) also opined that drip fertigation of RDF from 15 DAP to 210 DAP to sugarcane under pit method of sugarcane planting recorded the highest cane (190 t ha⁻¹) and sugar yield (19.8 t ha⁻¹) with benefit cost ratio of 3.10. Sujatha *et al.* (2006) observed that drip irrigation in cane resulted in realizing a net return of ₹. 68,581 ha⁻¹. Mohamed Amanullah *et al.* (2007) indicated that net return and B:C ratio were higher under drip irrigation compared to that of surface irrigation. However, cost benefit of cane cultivation was higher under surface irrigation in the first year of study owing to high initial installation cost of drip system.

The highest net income (₹.1,06,956 ha⁻¹) benefit cost ratio (2.01) and lower pay back period were realized in subsurface drip fertigation in sugarcane (Mahesh, 2009). Guruswamy and Mahendran (2010) observed that drip fertigation of 100 per cent RDF as water soluble fertilizer recorded 243.0 per cent higher net return over surface irrigation with soil application of recommended dose of fertilizer 220.7 per cent. The higher B:C ratio of 3.72 and 3.16 was observed under drip fertigation and surface irrigation, respectively.

The higher net income of ₹. 1,47,039 ha⁻¹, higher B:C ratio of 3.76 and lower payback period were realized with subsurface drip fertigation of 100 per cent RDF through water soluble fertilizers to ratoon sugarcane (Sathyaraj, 2010). Torres *et al* (2010) reported favourable economic results for the drip irrigation system over the gravity irrigation system for the sugarcane cultivation. Veeraputhiran *et al.* (2011) recorded that higher net income and B.C ratio of ₹. 1,41,790 ha⁻¹ and 2.69 under subsurface drip fertigation as compared to ₹. 93,562 ha⁻¹ and 2.15, respectively under soil application of RDF.

Hemalatha (2012) observed that application of N as urea fertilizer showed positive response up to 195.5 kg ha⁻¹ through subsurface drip irrigation, enhanced the B:C ratio. The treatment that received N@195.5 kg ha⁻¹ recorded the highest value of 3.63. Hence, this investigation has brought out the best nutrient management system using urea as an N source under fertigation as an effective and economic source for sugarcane. Pawar *et al.* (2013) opined that net income (208.3 × 10³ ₹. ha⁻¹), total income (489.3 × ₹. 10³ ha⁻¹) and water productivity (4.7 × 10³ ₹. cm⁻¹ of water used) over conventional method were higher in 100 per cent fertigation but all the economical parameters were on par with 100 per cent fertigation and 80 per cent fertigation. Hence, 80 per cent drip fertigation through water soluble fertilizers applied in 26 splits as per growth stages was found suitable for productive sugarcane cultivation.

Pawar *et al.* (2014) reported that higher net seasonal income (₹. 2,26,195 ha⁻¹) and net extra income over conventional method (₹. 66, 246 ha⁻¹) were obtained in 80 per cent subsurface drip fertigation. The application of 80 per cent water soluble fertilizers through drip irrigation was found to be the best practice to obtain better yield, improve nutrient and water use as well as cost economics.

Adoption of subsurface drip irrigation system for sugarcane cultivation helps in achieving higher net return and B:C ratio as compared to conventional method of cultivation.

III MATERIAL AND METHODS

Field investigation entitled “Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation” was carried out for two seasons in plant and ratoon cane during 2014-15 and 2015-16, respectively. Details of material used and the techniques adopted in conducting field experiments are presented in this chapter.

3.1 Location of the experimental site

Field experiments were conducted in F block of Zonal Agricultural Research Station, V.C. Farm, Mandya. The station is situated between 12° 18' and 13° 04' North latitude and 76° 79' and 77° 20' East longitude and at an altitude of 695 metre above mean sea level which falls in the Southern Dry Zone (Zone IV) of Karnataka.

3.2 Weather and climate

Monthly mean meteorological data was recorded at the Zonal Agricultural Research Station, Mandya. The normal weather data of 40 years (1974-2014) and actual weather parameters for the year 2014-15 and 2015-16 such as total rainfall, temperature (maximum and minimum), sunshine hours, relative humidity and pan evaporation are presented in (Table 3.1 and 3.2), Fig. 3.1a and 3.1b and Fig.3.2a and 3.2b.

3.2.1 Normal climatic condition

The average annual rainfall of the station is 710.7 mm, which was well distributed from April to November with two peaks, first peak in May and second in October.

The mean monthly maximum and minimum temperature ranges from 26.2°C to 31.7°C and 14.0°C to 19.4°C, respectively. The highest mean monthly temperature observed during March (31.7 °C) and the lowest during December (14.0 °C). In general, the lowest temperature was observed during the month of December and January and the highest during April and May.

The highest average relative humidity (RH) of 85.9 per cent and the lowest RH of 78.2 per cent were recorded during the month of October and April, respectively. The average daily evaporation (USWB pan evaporimeter) of 5.2 mm, with a peak of 7.0 mm was recorded in April. The duration of sunshine hour was the highest during July (9.0 h) and the lowest during August (4.6 h).

Table 3.1: Meteorological data of mean monthly normal and actual for the year 2014 at ZARS, VC farm, Mandya

Month	Rainfall (mm)			Temperature (°C)						S.H. hrs.			Relative humidity (%)			P.E. (mm day ⁻¹)		
	N	A	D	Max			Min			N	A	D	N	A	D	N	A	D
				N	A	D	N	A	D									
January	1.5	0	-1.5	29.3	29.3	0	14.0	13.2	-0.8	8.0	8.7	0.7	84.2	89.5	5.3	3.4	3.8	0.4
February	4.4	1.2	-3.2	29.9	31.1	1.2	15.4	16.1	0.7	6.4	7.9	1.5	82.1	86.6	4.5	4.0	4.4	0.4
March	15.2	36.1	20.9	31.7	30.2	-1.5	17.8	14.8	-3.0	5.9	7.5	1.6	81.8	83.4	1.6	5.0	5.5	0.5
April	51.4	20.8	-30.6	30.9	34.7	3.8	19.4	19.9	0.5	6.3	5.5	-0.8	78.2	84.6	6.4	5.2	5.4	0.2
May	90.6	243.2	152.6	30.1	34.1	4.0	18.9	20.4	1.5	7.5	7.0	-0.5	78.5	89.8	11.3	4.9	5.5	0.6
June	57.2	53.1	-4.1	27.8	32.5	4.7	18.5	19.7	1.2	8.1	5.9	-2.2	79.1	90.5	11.4	4.7	5.5	0.8
July	53.6	72.8	19.2	27.8	30.6	2.8	18.9	19.2	0.3	9.0	4.6	-4.4	83.9	88.1	4.2	4.0	4.1	0.1
August	72.4	114.6	42.2	28.2	29.1	0.9	18.9	19.6	0.7	4.6	3.5	-1.1	83.8	90.6	6.8	3.3	3.6	0.3
September	150.8	141.4	-9.4	28.3	30.6	2.3	18.9	18.4	-0.5	6.1	5.4	-0.7	84.1	90.5	6.4	3.8	4.1	0.3
October	145.9	237.5	91.6	28.1	30.8	2.7	18.6	18.3	-0.3	5.7	4.9	-0.8	85.9	91.4	5.5	3.3	3.3	0.0
November	53.3	10.4	-42.9	26.6	29.1	2.5	16.4	17.8	1.4	5.8	6.0	0.2	81.2	90.0	8.8	2.9	3.2	0.3
December	14.4	24.4	10.0	26.2	28.4	2.2	14.2	16.7	2.5	6.4	5.5	-0.9	80.3	90.0	9.7	3.3	3.1	-0.2
Total	710.7	955.5																

Max: Maximum**R.H: Relative humidity****A: Actual for the year 2014****N: Normal for previous 40 years (1974-2014)****Min: Minimum****S.H: Sunshine hours****P.E: Pan evaporation****D: Deviation from normal**

Table 3.2: Meteorological data of mean monthly normal and actual for the year 2015 at ZARS, VC farm, Mandya

Month	Rainfall (mm)			Temperature (°C)						S.H. hrs.			Relative humidity (%)			P.E. (mm day ⁻¹)		
	N	A	D	Max			Min			N	A	D	N	A	D	N	A	D
				N	A	D	N	A	D									
January	1.5	0	-1.5	29.3	29.0	-0.3	14.0	14.2	0.2	8.0	7.8	-0.2	84.2	89.2	5.0	3.4	3.1	-0.3
February	4.4	1.8	-2.6	29.9	31.1	1.2	15.4	13.7	-1.7	6.4	8.4	2.0	82.1	86.8	4.7	4.0	3.8	-0.2
March	15.2	0	-15.2	31.7	33.5	1.8	17.8	17.6	-0.2	5.9	7.3	1.4	81.8	83.6	1.8	5.0	4.7	-0.3
April	51.4	23.2	-28.2	30.9	33.8	2.9	19.4	19.6	0.2	6.3	6.4	0.1	78.2	84.4	6.2	5.2	5.2	0.0
May	90.6	135.3	44.7	30.1	32.8	2.7	18.9	19.6	0.7	7.5	2.2	-5.3	78.5	89.8	11.3	4.9	4.4	-0.5
June	57.2	60	2.8	27.8	30.1	2.3	18.5	19.8	1.3	8.1	4.7	-3.4	79.1	90.5	11.4	4.7	4.0	-0.7
July	53.6	1.2	-52.4	27.8	30.7	2.9	18.9	19.2	0.3	9.0	4.6	-4.4	83.9	88.2	4.3	4.0	4.1	0.1
August	72.4	67.8	-4.6	28.2	30.4	2.2	18.9	19.2	0.3	4.6	4.8	0.2	83.8	90.7	6.9	3.3	3.2	-0.1
September	150.8	82.6	-68.2	28.3	29.6	1.3	18.9	18.5	-0.4	6.1	5.1	-1.0	84.1	90.9	6.8	3.8	3.7	-0.1
October	145.9	47	-98.9	28.1	29.5	1.4	18.6	19.4	0.8	5.7	5.1	-0.6	85.9	91.7	5.8	3.3	3.5	0.2
November	53.3	168.6	115.3	26.6	29.4	2.8	16.4	15.3	-1.1	5.8	1.4	-4.4	81.2	90.5	9.3	2.9	2.7	-0.2
December	14.4	7.2	-7.2	26.2	29.0	2.8	14.2	15.0	0.8	6.4	4.6	-1.8	80.3	90.1	9.8	3.3	3.7	0.4
Total	710.7	594.7																

Max: Maximum**R.H: Relative humidity****A: Actual for the year 2014****N: Normal for previous 40 years (1974-2014)****Min: Minimum****S.H: Sunshine hours****P.E: Pan evaporation****D: Deviation from normal**

3.2.2 Actual climatic conditions during the cropping season

Actual rainfall during the year 2014 and 2015 was 955.5 mm and 594.7 mm, respectively as against normal rainfall of 710.7 mm recorded for the last 40 years. The rainfall during the crop period was less than normal in the month of February, April, June and November during 2014 and February, April, July, October and December during 2015. The mean maximum temperature during the period of experimentation ranged from 28.4°C to 34.7°C in 2014 and 29°C to 33.8° C in 2015. The mean minimum temperature ranged from 13.2 ° C to 20.4 ° C during 2014 and 13.7° C to 19.8°C during 2015. The higher relative humidity of 91.4 and 91.7 percent was recorded in October month in both the years. The maximum actual sunshine hours was observed in the month of January (8.7) during 2014 and February (8.4) during 2015.

3.3 Soil characteristics of the experimental site

The soils of the experimental site belongs to the order Alfisols and the topography of the experimental plot was uniform with a slope of 2 per cent. The data on mechanical and chemical analysis of the soil samples are given in Table 3.3. Texturally the soils are red sandy loam with neutral in reaction, low in organic carbon, medium in available nitrogen, phosphorus and potassium.

3.4 Previous crop in the experimental field

Sugarcane was grown in the plot during 2013 before the plant crop of the experiment.

3.5 Experimental details

The study included plant and ratoon crop of sugarcane and the details of the experiment are described below.

Crop	: Sugarcane
Experiment location	: ZARS, VC Farm, Mandya
Experiment year	: 2014-15 : 2015-16
Season	: 1 st season plant cane : 2 nd season ratoon cane
Variety	: Co-86032
Experiment design	: Factorial RCBD
Treatments	: 15+1
Replications	: 3
Gross plot size	: 15 m × 9 m
Net plot size	: 8 m × 8 m
Spacing	: (165+30) × 30 cm

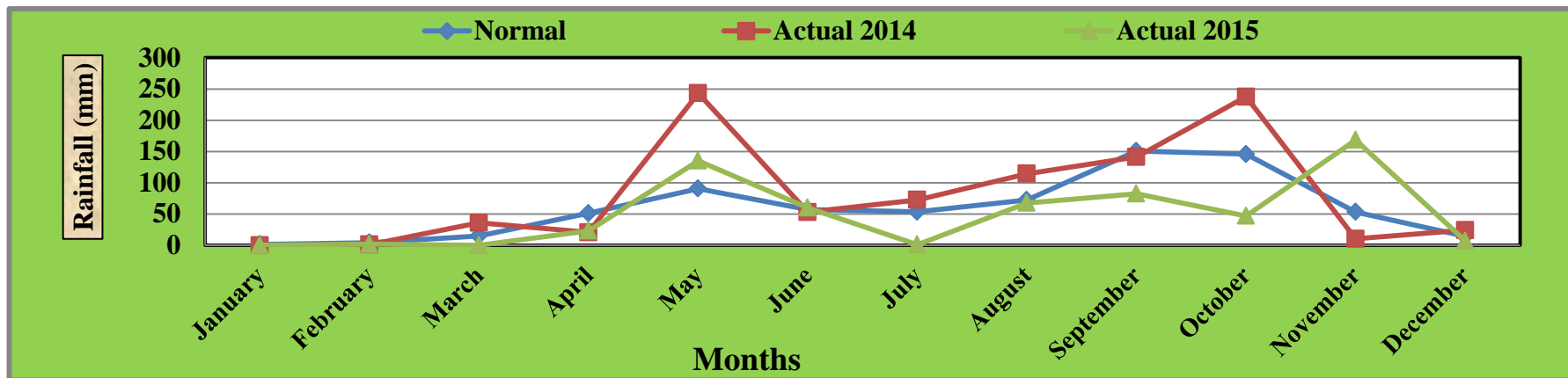


Fig. 3.1a: Normal (Avg. of 40 years) and actual rainfall during cropping period of 2014 and 2015

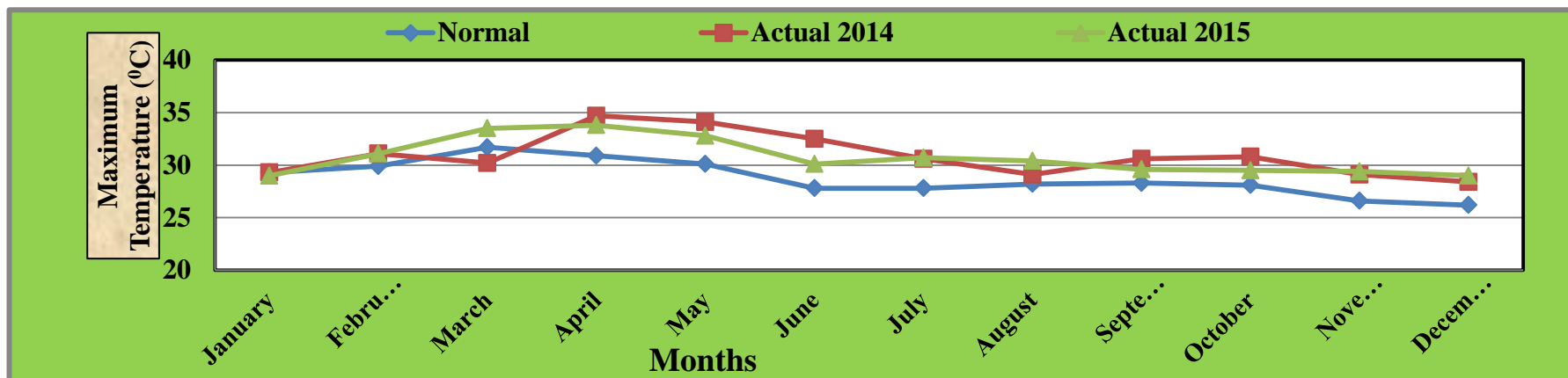


Fig. 3.1b: Normal (Avg. of 40 years) and actual maximum temperature during cropping period of 2014 and 2015

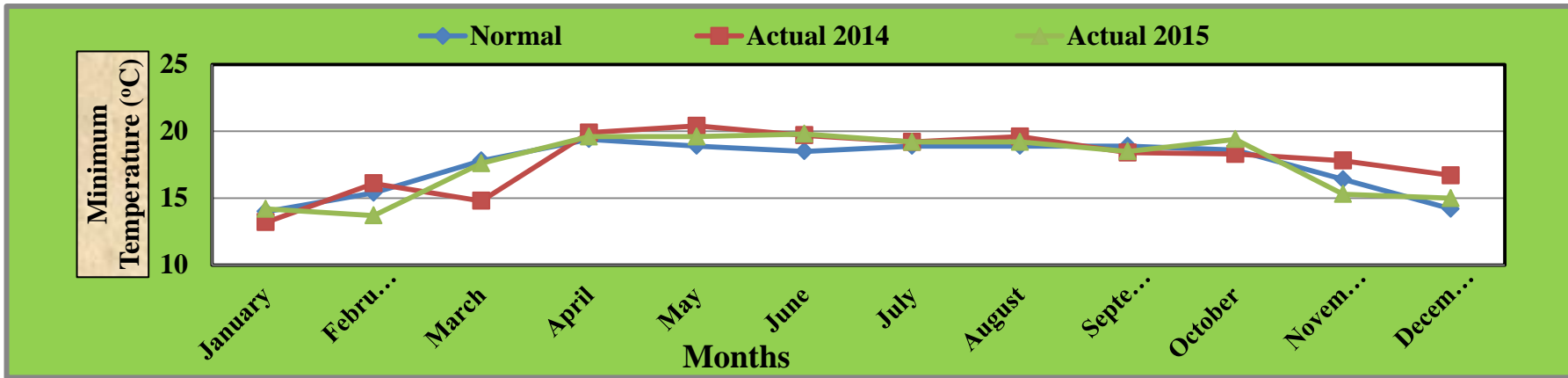


Fig. 3.2a: Normal (Avg. of 40 years) and actual minimum temperature during cropping period of 2014 and 2015

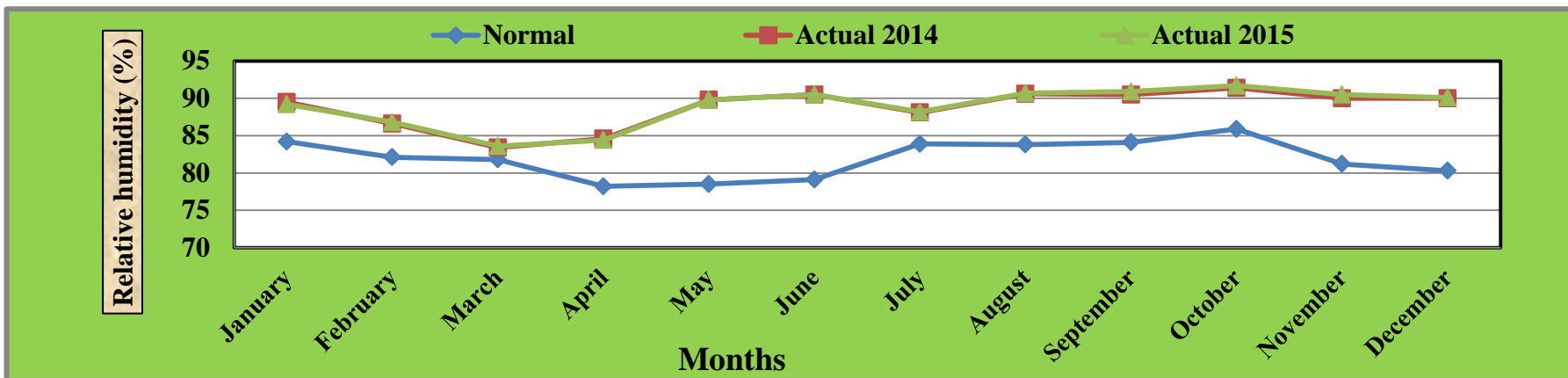


Fig. 3.2b: Normal (Avg. of 40 years) and actual relative humidity during cropping period of 2014 and 2015

3.5.1 Treatment details

Factor A

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation.

Note: (RDF- 250:100:125 kg NPK ha⁻¹)

Table 3.3: Physical and chemical properties of soil in the experimental site

Particulars	Values	Status	Method followed
I. Physical properties			
1.Coarse sand (%)	53.4		International pipette method (Piper, 1966)
2. Fine sand (%)	14.3		
3. Silt (%)	16.6		
4. Clay (%)	15.2		
5. Soil type	Red sandy loam		
II. Chemical properties			
1. pH (1:2.5)	6.92	Neutral	Buckman's Zero metric pH meter (Piper, 1966)
2.EC (1:2.5) (dSm ⁻¹)	0.162	Low	Conductometry (Jackson, 1973)
3.Organic carbon (%)	0.46	Low	Wet digestion method (Walkley and Black, 1934)
4. Available N (kg ha ⁻¹)	292.5	Medium	Alkaline permanganate method (Subbaiah and Asija, 1956)
5.Available P ₂ O ₅ (kg ha ⁻¹)	38.2	Medium	Olsen's method (Jackson, 1973)
6. Available K ₂ O (kg ha ⁻¹)	178.3	Medium	Neutral normal ammonium acetate method (Jackson, 1973)

3.6 Cultural practices

3.6.1 Land Preparation

The land was prepared by ploughing with tractor drawn disc plough followed by disc harrowing and passing cultivator twice to bring the soil to fine tilth. The experimental area was divided into three replications and each replication consists of 6 plots including control and treatments were allotted randomly and laid out as per the factorial RCBD given in plan of layout Fig. 3.3.

3.6.2 Drip system installation

Drip irrigation system was installed which included pump, filter units, main line and sub line for each replication and a lateral for each plot in the experiment. The water source was bore well and it was pumped through 7.5 HP motor and conveyed to the main field using 90 mm PVC pipes after filtering through sand and screen filter. From the mainline, water was taken to the field through sub mains of 63 mm diameter PVC pipes. The laterals were placed at 1.95 m apart. The drip line was passed in between 30 cm apart paired row at 20 cm below the surface of soil. Inline emitters were placed 40 cm apart with a discharge rate of 4 lph.

3.6.3 Fertilizer application

Recommended dose of FYM was applied at the rate of 25 t ha⁻¹ one week before planting and normal grade of fertilizers were used for fertigation of treatments. Out of the recommended dose of fertilizer (250:100:125 kg of NPK ha⁻¹), entire dose of phosphorus was applied as soil application in two splits at basal (50 %) and remaining at 105 days after planting (50 %) while earthing up. Entire dose of N and K was applied through subsurface drip fertigation at different duration of 3.5, 5.0, 6.5, 8.0 and 9.5 months consisting of 28, 40, 52, 64 and 76 splits of fertigation respectively, twice in a week and drip irrigation was scheduled for every two days with three fertigation levels of 75 per cent RDF (187.5:75:93.75 kg of NPK ha⁻¹), 100 per cent RDF (250:100:125 kg of NPK ha⁻¹) and 125 per cent RDF (312.5:125:156.25 kg of NPK ha⁻¹). For the plots receiving 100 percent RDF treatment (control), the entire dose of potassium (125 kg ha⁻¹) was applied as basal dose. Whereas, nitrogen and phosphorus were applied in split doses i.e. 10% N+50% P as basal, 20 % N at 4 weeks after planting, 30 % N at 10th week after planting and remaining 40 % N+50 % P at 105 DAP as normal method of cane cultivation.

3.6.4 Setts and planting

Two eye budded setts were collected from a well grown 9 month old plant crop of sugarcane. The plant crop experiment was planted on 13th January, 2014 with a sett rate of 23,500 setts ha⁻¹ by wet method of planting. Setts were planted in furrows in a zig zag manner by pressing in the furrow by letting the water into furrows.

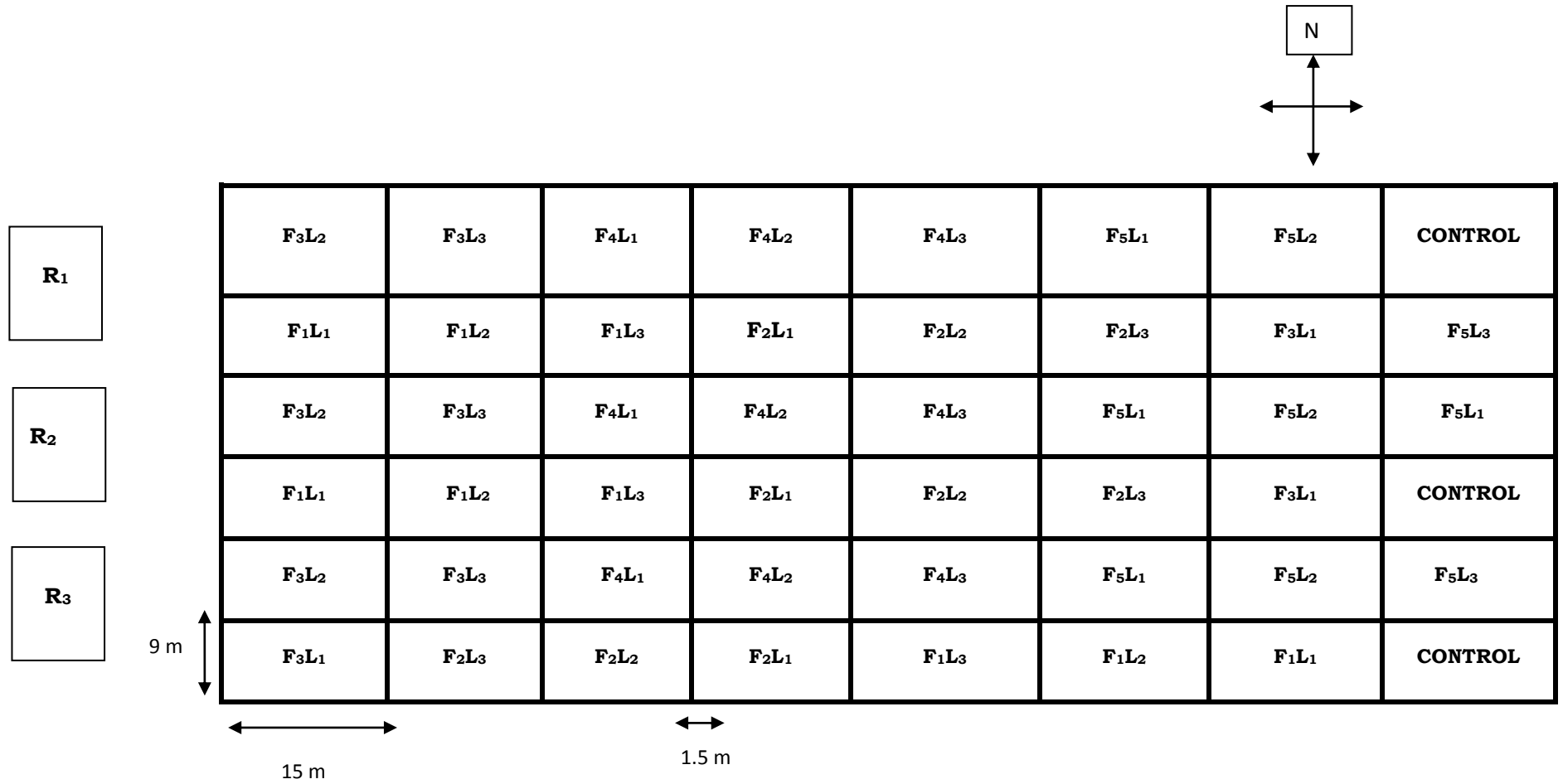


Fig. 3.3: Plan of layout of the experiment

3.6.5 Intercultural operations

Earthing up was carried out by tractor drawn implement at 105 days after planting for plant crop and 90 days after planting for ratoon crop. Wrapping and propping were done when the crop attained 10 months of age to prevent lodging.

3.6.6 Trash management in ratoon crop

Sugarcane trash which was left over after the harvest of the plant crop was effectively decomposed by the utilization of microbial consortia. The consortia comprised of two microorganisms viz., *Pleurotus sajorcaju* and *Trichoderma viride*. The treatments which were imposed for the plant crop was similarly followed for ratoon crop without any modification to study the sustainability in growth and yield parameters of sugarcane as influenced by drip fertigation.

3.6.7 After care

3.6.7.1 Weeding

Weed management was done through application of pre emergent herbicide Metribuzin 70 per cent @ 600 g ha⁻¹ at 3 days after planting followed by hand weeding at 45 and 90 days after planting to keep the plots weed free.

3.6.7.2 Plant protection measures

Chlorophyriphos @ 4 lit ha⁻¹ was applied through subsurface drip for the control of root grub during both the years of crop.

3.6.7.3 Harvesting

The plant crop was harvested between 25th and 28th January, 2015. The ratoon crop was initiated by following the cultivation practices of stubble shaving, shoulder breaking, gap filling and thrash management practices. Ratoon crop was harvested between 11th and 14th January 2016.

3.7 Collection of experimental data

The procedures adopted for recording various phenological, physiological, qualitative, chemical and other analytical procedures on cane, juice, jaggery and soil parameters are discussed in the following section. The observations recorded and the procedures adopted were common in both plant and ratoon experiments, unless it is mentioned.

3.7.1 Growth parameters

The growth parameters were recorded at 60, 120, 180, 240, 300 DAP and at harvest



Plate 1: Land preparation



Plate 2: Drip system installation



Plate 3: Sugarcane setts planting



Plate 4: General view of the field experiment

3.7.1.1 Plant height (cm)

The plant height of five randomly selected canes in each clump was measured from the base of the plant to fully opened base of the top leaf and mean height was calculated and expressed in centimetre.

3.7.1.2 Number of tillers m⁻¹

The tillers were counted from five randomly selected one metre row length and recorded as number of tillers m⁻¹.

3.7.1.3 Leaf area (LA) (dm²m⁻¹)

The leaf area was calculated by multiplying with a factor 0.75 (Romero, 1978). The mean leaf area of selected leaves was multiplied by number of leaves per plant to arrive at the leaf area per plant and expressed in decimetre square.

3.7.1.4 Leaf area index (LAI)

Leaf area index is defined as leaf area per unit land area (Sestak *et al.*, 1971). The total leaf area was divided by the land area occupied by the plants.

$$\text{LAI} = \frac{A}{P} = \frac{\text{Total leaf area}}{\text{Land area occupied}}$$

3.7.1.5 Total dry matter production (g plant⁻¹)

The five canes selected from dry matter sampling rows were cut at the base and kept for air drying in shade. The semi dried material was kept in hot air oven at 55-70°C till it reaches constant weight and oven dry weight was recorded. After weighing, the total dry matter production was calculated and was expressed in grams per plant.

3.7.1.6 SPAD (Soil and plant analysis development)

SPAD chlorophyll meter developed from Minolta (Minolta Ltd, Tokyo, Japan) was used for recording SPAD values in sugarcane leaf. The SPAD chlorophyll meter readings were recorded at middle lamina of the third leaf from the top of millable cane at 120, 240 DAP and at harvest.

3.7.2 Yield parameters

3.7.2.1 Number of millable canes (m^{-1} length)

At harvest, all the canes from each treatment were cut, dressed, counted in randomly selected meter row length and recorded as number of millable canes m^{-1} length.

3.7.2.2 Single cane weight (kg)

The weight of five millable canes was recorded and the average was worked out at harvest and expressed as single cane weight in kilograms.

3.7.2.3 Cane length (m)

The height of five randomly selected millable canes in each clump was recorded from the ground level to the base of the fully opened last leaf (last internode) and the average was worked out and expressed in metres.

3.7.2.4 Cane girth (cm)

The diameter of cane was recorded by using Vernier callipers and expressed in centimetres. The diameter at top, middle and bottom portion of cane was measured and averaged.

3.7.2.5 Number of internodes cane⁻¹

The internodes present on the stalk upto the last fully opened leaf were recorded from five canes in each treatment. The mean number of internodes per cane was worked out and expressed as number of internodes cane⁻¹.

3.7.2.6 Cane yield (t ha^{-1})

All the canes in the net plot were cut close to the ground level. The green tops and trash were removed and cane yield per net plot was recorded at harvest and converted into hectare basis and expressed as tonnes per hectare.

3.7.2.7 Sugar yield or commercial cane sugar yield (t ha^{-1})

Sugar yield was calculated by using the following formula as suggested by Sastry and Venkatachari (1960).

$$\text{Sugar yield [t ha}^{-1}] = \frac{\text{CCS [\%]} \times \text{cane yield [t ha}^{-1}]}{100}$$

Where,

CCS = Commercial cane sugar (%)

3.7.2.8 Water productivity/ Water use efficiency

Water use efficiency was worked out by dividing sugarcane yield by the amount of water used (Viets, 1972) and expressed in $t\ ha^{-1}\ cm^{-1}$

$$WUE = \frac{\text{Cane yield [t ha}^{-1}\text{]}}{\text{Quantity of total water applied (cm)}}$$

3.7.3 Sugarcane juice quality parameters

The juice samples extracted from a power driven sugarcane crusher from five canes selected at random from the net plot area at harvest were analyzed for the following quality parameters.

3.7.3.1 Juice extraction (%)

$$\text{Juice extraction per cent (\%)} = \frac{\text{Juice weight}}{\text{Cane weight}} \times 100$$

3.7.3.2 Brix (%)

The brix readings of the filtered juice samples were recorded with the help of brix hydrometer standardized for $27.5^{\circ}\ C$. The juice temperatures were recorded for necessary temperature corrections and expressed as per cent Brix.

3.7.3.3 Sucrose or Pol (%)

The juice samples were clarified as per Horne's dry lead sub acetate clarification method (Meade - Chen, 1977) and filtered through Whatman number 1 filter paper. The pol per cent readings of the filtrates were recorded with the help of polariscope. The pol readings obtained were correlated with observed degrees brix with the help of Schmitz's table so as to get the values of pol per cent juice which is synonymously used for sucrose per cent juice.

3.7.3.4 Purity (%)

It is the ratio of pol per cent juice to the corrected degrees brix expressed in percentage and the values were computed as per the following formula.

$$\text{Purity coefficient} = \frac{\text{Pol per cent juice}}{\text{Corrected brix \%}} \times 100$$

3.7.3.5 Commercial cane sugar (CCS %)

It is the amount of white commercial sugar that can be obtained from total cane juice after removing total soluble solids. The values of commercial cane sugar on per cent cane basis were computed from the following formula.

$$\text{CCS per cent cane} = \left\{ S - (B - S) \times 0.4 \right\} \times 0.73$$

Where,

S=sucrose per cent in juice

B= brix per cent in juice

3.7.3.6 Reducing sugars (%)

Percentage of reducing sugars was obtained by using the Lane and Eynon (original) method by using Fehling A and Fehling B solutions as explained by Varma (1988).

$$\text{Reducing sugars (\%)} = \frac{0.05 \times \text{Volume of jaggery solution}}{\text{Titer value} \times \text{weight of jaggery}} \times 100$$

3.7.7 Jaggery quality parameters

Jaggery samples were prepared and analysed in the laboratory at harvest as per the method standardized by Roy (1951) and graded according to quality parameters.

Jaggery preparation

The five randomly selected cane samples from each plot were used for jaggery preparation and processed. The jaggery samples were stored for further observations.

The steps followed in jaggery preparation

1. **Cane crushing:** Five randomly selected cane samples during harvest were crushed in horizontal three roller crusher having juice extraction efficiency of about 65 per cent.
2. **Juice Filtration:** The extracted juice was cleaned by using two stage filtration system. While transferring the juice from storage tank to the boiling pan, it was passed through nylon cloth for filtration.
3. **Juice boiling:** The extracted juice was taken to boiling pan for jaggery processing. Dried cane bagasse was used as fuel for boiling. The pH of fresh juice ranges between 5.2 and 5.4 which was raised up to 6.5 by using lime

(CaO₃). The neutral pH of juice facilitates the coagulation of suspended impurities of gummy colloidal substances. It also helps in avoiding inversion of sugar. For this purpose, calculated lime solution prepared by dissolving lime @ 150- 200 g in 5 litres of water was added to cane juice.

4. **Juice clarification:** For clarification of juice, the vegetative clarificants, wild okra/bhendi plant (*Abelmoschus esculentus*) stalk extract was used. This extract was prepared by crushing 2 kg of okra plant stalk and soaked in 15 litres of water. The filtered extract is added to juice for clarification. At 85°C temperature, the nitrogenous impurities in juice starts coagulating and float on surface as black scum which was removed by using strainer. Scum removal operation is very important unit of operation in the jaggery processing and efficiency of this operation decides the quality of jaggery. Removal of second golden scum should be carried out during boiling as and when it appears on top of boiling juice.
5. **Juice concentration:** After clarification of juice, when temperature rises to about 99° to 100°C, the juice begins to froth. To control excess frothing and to avoid loss of juice due to overflowing, continuous stirring was applied by specially fabricated churner. After defrothing, juice gets concentrated at 104°– 105°C temperature, and liquid jaggery stage is attained. The liquid jaggery is further concentrated and groundnut edible oil @ 200 ml /1000 litre of juice was mixed. Application of edible oil helps to increase temperature of liquid without caramelization. The electronic thermometer with 1 m long sensor attached to the boiling pan was used for accurate recording of juice temperatures at different stages and thereby to monitor the Jaggery processing.
6. **Jaggery cooling and Moulding:** When juice temperature raises to 118°± 0.5°C, the jaggery stage was observed. This stage could be ascertained by jaggery ball test. Immediately after this stage, the boiling pan was removed from furnace and hot jaggery was poured in to cooling tray. During cooling, two stirrings are given to hot jaggery with wooden ladles. This stirring application helps to improve colour and granularity of jaggery. Before the temperature of jaggery drops down to 76°C, the hot jaggery mass is filled to moulds. After complete cooling, jaggery was removed from moulds and allowed to dry for 48 hrs. For experimental sample, SS trays were used to cool the jaggery syrup.

3.7.4.1 Net rendament value (NR)

Net rendament values were calculated by substituting the jaggery quality values in the formula given below.

$$\text{Net rendement value} = \text{Sucrose (\%)} - \left\{ \text{R.S \%} + (3.5 \times \text{Ash \%}) \right\}$$

Where,

R.S= Reducing sugar

Based on the NR values, the jaggery samples were classified and graded according to the scale proposed by Khanna and Chakravarthi, (1954).

NR values	Grade	Quality
>65	A ₁	Excellent
60-65	A ₂	Good
45-60	B	Medium
<45	C	Poor

3.7.4.2 Jaggery recovery (%)

$$\text{Jaggery recovery (\%)} = \frac{\text{Weight of jaggery obtained} \times \text{total weight of juice}}{\text{Weight of juice used for jaggery preparation} \times \text{weight of cane}} \times 100$$

3.7.4.3 Jaggery yield (t ha⁻¹)

Jaggery yield was calculated by multiplying cane yield (t ha⁻¹) with jaggery recovery per cent and it is expressed in tonnes ha⁻¹.

$$\text{Jaggery yield (t ha}^{-1}\text{)} = \frac{\text{Cane yield t ha}^{-1} \times \text{jaggery recovery \%}}{100}$$

3.7.4.4 Reducing sugars in jaggery

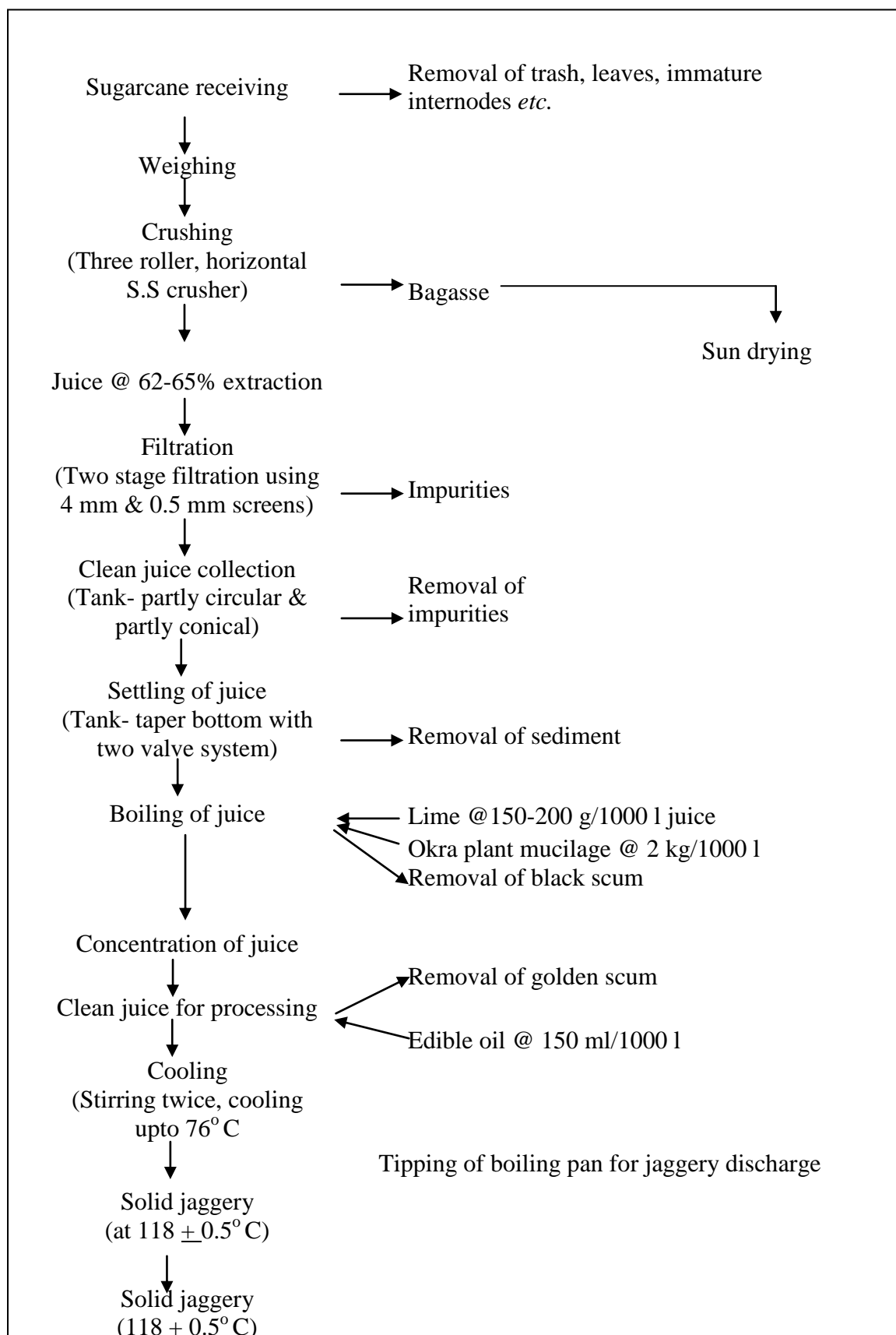
The reducing sugars were estimated by titrating the jaggery solution (10 g dissolved in 100 ml of water and clarified with lead sub acetate of activated charcoal) with 10 ml of Fehlings A + B solution as per Lane and Eynon volumetric method (Miller, 1998).

$$\text{RS in jaggery} = \frac{0.05 \times \text{volume of jaggery solution}}{\text{Titer value} \times \text{weight of jaggery}} \times 100$$

3.7.4.5 Jaggery hardness

Jaggery hardness was tested by using hardness tester by placing 3 cm³ of jaggery in the hardness tester and force is applied to break the cube and the reading was recorded and it is expressed in kg cm³.

Flow chart of jaggery production processing



3.8.5 Available soil nutrients

The available nutrients in the soil such as nitrogen, phosphorus and potassium were estimated at initial and final stages in both plant and ratoon crop experiment. The representative soil samples were collected from individual plots from a depth of 0-30 cm by quatering technique and samples were dried under shade, powdered and used for analysis.

3.8.5.1 Estimation of available nitrogen

Available nitrogen was estimated by using alkaline potassium permanganate method (Subbiah and Asija, 1956). A known quantity of soil sample (5 g) was distilled in a distillation apparatus with the addition of 0.32 per cent potassium permanganate (100 ml) followed by 2.5 per cent sodium hydroxide (100 ml). The distillate collected in 2 per cent boric acid (25 ml) was back titrated with standard sulphuric acid (0.05 N) using mixed indicator (Bromocresol green and methyl red) and available nitrogen in soil was calculated using.

$$\text{Avail. nitrogen (kg ha}^{-1}\text{)} = \frac{\text{Titre value} \times \text{normality of H}_2\text{SO}_4 \times 0.014 \times 100}{\text{Weight of soil}}$$

3.8.5.2 Estimation of available phosphorus

Available phosphorus was estimated by using Olsen's method (Jackson, 1973). A known quantity of soil sample (5 g) was shaken with 50 ml Olsen's reagent 0.5 N sodium bicarbonate with pH adjusted to 8.5 + Darco G 60 (1 g) in a polythene bottle followed by filtering. A known quantity of filtrate (5 ml) was added with 1.5 per cent ammonium molybdate (5 ml) and 1:6 sulphuric acid (5ml) followed by stannous chloride solution (1 ml) and allowed for development of blue colour after making up the volume to 25 ml. The intensity of blue colour was measured in spectrophotometer at 660 nm. The concentration of phosphorus (ppm) in the aliquot was found out with the help of standard curve prepared from the standard stock solutions of known concentrations of phosphorus.

$$\text{Avail. P}_2\text{O}_5 \text{ (kg ha}^{-1}\text{)} = \frac{\text{Graph ppm} \times \text{vol. of extractant} \times \text{vol. made} \times 2 \times 10^6 \times 2.29}{10^6 \times \text{weight of soil} \times \text{aliquot taken}}$$

3.8.5.3 Estimation of available potassium

The available potassium was estimated by following neutral normal ammonium acetate method using flame photometer (Jackson, 1973). A known quantity of soil sample (5 g) was shaken with neutral normal ammonium acetate solution (25 ml) in a polythene bottle followed by filtration. The filtrate was fed to the flame photometer and the reading was recorded. The concentration of potassium



Plate 5: Jaggery preparation

(ppm) in the filtrate was found out with the help of standard curve prepared from the standard stock solution of known concentrations of potassium.

$$\text{Avail. K}_2\text{O (kg ha}^{-1}\text{)} = \frac{\text{Graph ppm} \times \text{vol. of extractant} \times 2 \times 10^6 \times 1.20}{10^6 \times \text{weight of soil}}$$

3.8.6 Crop nutrient uptake

Uptake of N, P and K by the crop was calculated based on the nutrient content (%) in different parts of the plant multiplied by their corresponding dry weight per millable cane and millable cane population per hectare. The nutrient content obtained from third leaf from the top after three to five months of planting (leaves and stem) was multiplied with dry matter of the plant to know the nutrient uptake by the plant and it is expressed in terms of kg ha⁻¹. The procedures adopted for analyzing the nutrient content in plants are as follows.

Nutrient	Method	Author
Nitrogen	Microkjeldahl's method	Jackson (1973)
Phosphorus	Vanado- molybdo phosphoric acid yellow colour method	Jackson (1973)
Potassium	Flame photometer method	Jackson(1973)

3.8.6.1 Nutrient use efficiency

Nutrient use efficiency was calculated by using the formula and expressed in t kg⁻¹ (Crasswell and Godwin, 1974).

$$\text{NUE} = \frac{\text{Cane yield [t ha}^{-1}\text{]}}{\text{Nutrient applied [kg ha}^{-1}\text{]}}$$

3.9. Microbial population analysis

3.9.1 Enumeration of bacteria, fungi and actinomycetes

Soil samples were collected from each plot before imposing the treatment and after the harvest of the canes for enumeration of bacteria, fungi and actinomycetes by using serial dilution and plate count method as described by Bunt and Rovira (1955), Martin (1950) and Kuster and Williams (1964), respectively.

10 g of soil sample was transferred separately to 90 ml sterile water blank and the flasks were shaken on a mechanical rotary shaker for five minutes to ensure uniform dispersion of soil particles in water to make 10^{-1} dilution. From these 10^{-1} dilutions, further tenfold dilutions were prepared by pipetting out one ml of the original suspension by using sterile pipette into nine ml sterile water blanks, so as to obtain the appropriate dilutions (10^{-2} , 10^{-3} , 10^{-4} , 10^{-5} and 10^{-6}). For isolation of bacteria, fungi and actinomycetes, dilutions of 10^{-6} , 10^{-3} and 10^{-4} were used respectively. Nutrient agar, Martin rose bengal agar and Kuster's agar media were used for bacteria, fungi and actinomycetes isolation, respectively at the rate of 50 ml per petri dish. Four replications were maintained for each group of organisms mentioned above. The incubation of petri dishes was done at $28 \pm 2^\circ\text{C}$ using an incubator for five days. Colonies were counted and expressed per unit weight of soil.

$$\text{Microbial population} = \frac{\text{Average number of colonies} \times \text{dilution factor}}{\text{Dry weight of the soil sample}} \text{ (No.} \times \text{CFU g}^{-1}\text{)}$$

3.10 Economic analysis

3.10.1 Cost of cultivation

The prices of the inputs that were prevailing at the time of their use were taken into account to work out the cost of cultivation. The labour wages, cost of inputs and outputs are furnished in Appendix I for both the sugarcane cultivation and jaggery preparation, respectively.

3.10.2 Gross return

Gross return was calculated using the cane yield (t ha^{-1}) and the prices of crop commodities at the time of marketing.

3.10.3 Net return

The net return per hectare was calculated by deducting the cost of cultivation per hectare from gross return per hectare.

$$\text{Net return} = \text{Gross return} - \text{total cost of cultivation}$$

3.10.4 Benefit cost ratio (B:C ratio)

$$\text{B:C ratio} = \frac{\text{Gross return } (\text{₹ ha}^{-1})}{\text{Cost of cultivation } (\text{₹ ha}^{-1})}$$

3.11 Statistical analysis

Data recorded in various observations *viz.*, growth, yield and soil parameters were subjected to analysis of variance given by Rangaswamy (2010). The level of significance used in “F” and “T” tests were at $p < 0.05$, critical difference values were calculated wherever the “F” test was found to be significant.

IV RESULTS AND DISCUSSION

Soil, nutrients and water are the major resources for sustenance of agriculture, which are becoming scarce and costly day by day. Inadequate supply and inefficient use of these resources is not only affecting resource base but also resulting in inconsistent production. In this view, drip irrigation and fertigation need extensive studies particularly in nutrient exhaustive, heavy water demanding and cost prohibitive crop like sugarcane. Hence, an investigation on “Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation” was conducted during 2014-15 and 2015-16 seasons comprising of plant cane and ratoon cane, respectively. The results of the investigation are presented and discussed in detail along with the causes of variation among the treatments in this chapter.

4.1 Weather and crop growth

Environment is basic and fundamental factor determining the growth of plants. Thus, the fluctuations in weather conditions directly affect the crop growth and development, and finally the expected yield. Eghball *et al.* (1995) reported that the management practices may in some cases reduce temporal variability but in other cases it will 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 agroclimatic situation. In this context, the weather conditions prevailed during the period of experimentation would definitely have a direct bearing on the productivity of any crop in general and sugarcane in particular. The crop at the location of experiment experienced favourable weather conditions during growth period as indicated by the climatic data in Table 3.1 and 3.2 and Fig3.1a, 3.1b and 3.2a, 3.2b. The weather parameters such as rainfall, maximum and minimum temperatures and relative humidity were conducive to the crop during the growth period and there was no incidence of any major pest and disease outbreak. The actual rainfall during crop growth period was less than normal in the month of February, April, June and November during 2014, and February, April, July, October and December during 2015. However, crop growth and development was not much affected by rainfall since the crop was grown under irrigated conditions. In addition, the prevailing temperature, relative humidity and actual sunshine hours were found optimum and favourable for the sugarcane growth and development during crop growth period in both the seasons.

4.1.1 Growth parameters

Plant growth is dependent on the rate of accumulation of dry matter, the dry matter accumulation may reflect on the economic yield in view of the fact that in sugarcane, vegetative part of the plant serves as source, where as the millable canes are the sink. The need for increased crop production is an outcome of a series of intermediate interaction of various biological events involving bio-chemical, physiological and morphological changes which takes place during the development in accordance with the supply of light, water, temperature and nutrients (Donald, 1962). Observations on various growth parameters like plant height, number of tillers, leaf area, leaf area index and total dry matter production was taken at 60, 120, 180,

240, 300 DAP and at harvest and these growth parameters are presented and discussed in this chapter.

4.1.1 Plant height (cm) (Table 4.1.1a and 4.1.1b)

Plant height did not differ significantly at 60 DAP due to fertigation duration and fertigation levels. Drip fertigation at 120 DAP (141.1 and 133.8 cm) recorded taller plants in plant and ratoon cane, respectively compared to other growth stages. Whereas, drip fertigation upto 9.5 months recorded significantly higher plant height at 180, 240, 300 DAP and at harvest (270.7 and 253.5 cm, 310.2 and 288.5 cm, 325.2 and 298.0 cm, 330.6 and 296.2 cm, respectively) as compared to other drip fertigation treatments upto 3.5, 5.0 and 6.5 months except drip fertigation upto 8 months (264.5 and 245.9 cm, 299.2 and 279.8 cm, 317.7 and 290.1 cm, 321.0 and 291.0 cm, respectively) which was recorded on par with drip fertigation upto 9.5 months.

Sub surface drip fertigation level did not influence significantly on plant height irrespective of growth stages.

The interaction effect of drip fertigation duration and fertigation levels showed significant difference at early and later stages of crop growth both in plant and ratoon cane. Drip fertigation upto 3.5 months with 125 per cent RDF recorded taller plants at 60 DAP (53.9 and 67.8 cm) in plant and ratoon cane. Numerically lower plant height was recorded with drip fertigation upto 3.5 months with 75 and 100 per cent RDF. Significantly higher plant height at 120 DAP in plant and ratoon cane with drip fertigation upto 3.5 months with 125 per cent RDF (142.3 and 136.5 cm) on par results were observed with 100 per cent RDF (140.85 and 133.51) and with 75 per cent RDF (140.3 and 131.4) in plant and ratoon cane. However, drip fertigation upto 5 months with 75 per cent RDF (133.7 and 126.7), 100 per cent RDF (134.4 and 129.6) and 125 per cent RDF (137.7 and 131.0) did not differ significantly in plant height. Moreover, at 180, 240, 300 DAP and at harvest significant differences in plant height was observed with drip fertigation duration upto 9.5 months with application of 125 per cent RDF through drip fertigation (272.5 and 256.2 cm, 313.4 and 290.4 cm, 330.1 and 303.0 cm, 332.5 and 299.5 cm), respectively. This was statistically on par with drip fertigation upto 9.5 months with 100 per cent RDF (270.5 and 252.9, 310.3 and 289.0, 324.8 and 296.9, 331.6 and 295.4, respectively) and with 75 per cent RDF (269.0 and 251.4, 306.9 and 286.3, 320.6 and 294.0, 327.7 and 293.7, respectively). However, lower plant height at 60 DAP (45.9 and 56.2 cm) and significantly lower plant height at 120, 180, 240, 300 DAP, and at harvest with surface furrow flood irrigation with application of 100 per cent RDF (105.1 and 97.8 cm, 229.2 and 211.1 cm, 265.3 and 233.3 cm, 273.3 and 256.3, 281.4 and 259.1 cm, respectively).

Higher plant height observed under sugarcane with subsurface drip fertigation might be due to continuous availability of required moisture nearer the crop root zone, which might have resulted in higher nutrient uptake resulting in greater cell division and elongation. It is well known fact that under reduced moisture condition all the

growth factors are affected adversely to greater extent under conventional irrigation method i.e. surface irrigation with RDF through soil application. Similar results were also reported by Sivanappan *et al.* (1996) who stated that higher frequency of irrigation and increased availability of soil moisture under drip irrigation have led to effective absorption and utilization of available nutrients and better proliferation of roots resulting in quick canopy growth. Aujla *et al.* (2005) reported that higher plant height was mainly due to readily availability of nutrients to plants at right stage of crop growth led to formation of two to four joints per month since higher nutrient requirement was needed for the metabolism of differentiation of newly formed cells in the elongation process to take place in subsequent stages. The above results are in conformity with the findings of Mahendran *et al.*, (2005); Subramani (2008) reported that drip fertigation of 100 per cent RDF as water soluble fertilizer based on crop growth stage resulted in an increase in plant height as compared to soil application of fertilizers. Similarly, fertigation based on stage wise nutrient requirement of sugarcane crop resulted in increased plant height. Balaji (2005); Kathiresan and Narayanasamy (1990) also reported that higher plant height was observed with increasing fertigation level. The result of present investigation is in agreement with the findings of Shanmugam *et al.* (2007) who also reported that plant height was increased with drip fertigation of 125 per cent of recommended dose of fertilizer as compared to surface irrigation. Similar results were observed by Selvakumar (2006) in sugarcane.

4.1.2 Number of tillers m⁻¹ (Table 4.1.2a and 4.1.2b)

Tillering is an important growth parameter in sugarcane. The total tiller production and their survival reflect on the total number of millable canes at harvest which ultimately reflects on cane yield.

Significant differences was not observed at 60 DAP due to fertigation duration and fertigation levels. Drip fertigation upto 3.5 months recorded higher number of tillers m⁻¹ at 60 DAP (14.21 and 22.34) and significantly higher number of tillers m⁻¹ at 120 DAP (23.19 and 32.72) in plant and ratoon cane compared to other growth stages. However, drip fertigation upto 9.5 months recorded significantly higher number of tillers m⁻¹ at 180, 240, 300 DAP and at harvest (28.98 and 38.77, 32.93 and 42.98, 34.98 and 43.52, 34.66 and 43.33, respectively) as compared to other drip fertigation treatments upto 3.5, 5.0 and 6.5 months except drip fertigation upto 8 months which recorded (28.50 and 37.92, 32.27 and 42.16, 34.46 and 42.98, 34.21 and 42.77, respectively) and was on par with drip fertigation upto 9.5 months.

Drip fertigation level did not influence significantly on the number of tillers m⁻¹. irrespective of growth stages.

Table 4.1.1a: Plant height (cm) of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	60 DAP		120 DAP		180 DAP	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	53.7	67.5	141.1	133.8	243.7	222.9
D₂	53.0	66.9	135.3	129.1	249.9	228.3
D₃	52.3	66.3	129.9	122.4	256.0	237.1
D₄	51.7	65.9	124.9	116.9	264.5	245.9
D₅	51.2	65.4	119.6	111.4	270.7	253.5
S.Em ±	1.47	1.62	3.37	3.39	6.20	6.33
CD (p=0.05)	NS	NS	9.74	9.79	17.89	18.28
Fertigation levels (L)						
L₁	52.2	66.2	128.7	120.5	254.6	235.3
L₂	52.4	66.4	129.8	122.8	256.7	237.0
L₃	52.6	66.6	131.9	124.9	259.6	240.3
S.Em ±	1.14	1.25	2.61	2.62	4.80	4.90
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	53.5	67.3	140.3	131.4	240.6	220.6
D₁L₂	53.6	67.5	140.8	133.5	243.7	223.7
D₁L₃	53.9	67.8	142.3	136.5	247.0	224.3
D₂L₁	52.8	66.7	133.7	126.7	248.8	225.8
D₂L₂	53.0	66.9	134.4	129.6	249.1	227.1
D₂L₃	53.3	67.1	137.7	131.0	251.8	232.1
D₃L₁	52.1	66.2	128.8	120.1	253.2	235.0
D₃L₂	52.3	66.3	129.6	122.8	255.9	236.3
D₃L₃	52.5	66.5	131.2	124.2	259.0	239.9
D₄L₁	51.6	65.8	123.3	115.9	261.1	243.5
D₄L₂	51.8	65.9	124.1	116.6	264.5	245.2
D₄L₃	51.9	66.0	127.3	118.3	267.9	249.0
D₅L₁	51.0	65.2	117.5	108.2	269.0	251.4
D₅L₂	51.2	65.3	119.9	111.4	270.5	252.9
D₅L₃	51.4	65.6	121.3	114.4	272.5	256.2
Control	45.9	56.2	105.1	97.8	229.2	211.1
S.Em ±	2.55	2.80	5.84	5.87	10.73	10.96
CD (p=0.05)	NS	NS	16.86	16.95	30.99	31.66

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)

Table 4.1.1b: Plant height (cm) of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	240 DAP		300 DAP		At harvest	
Fertigation duration (D)						
Fertigation duration	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D ₁	279.3	250.0	290.8	269.7	296.2	273.4
D ₂	284.6	258.3	297.3	274.9	304.9	279.6
D ₃	290.8	270.0	308.8	280.9	313.0	285.4
D ₄	299.2	279.8	317.7	290.1	321.0	291.0
D ₅	310.2	288.5	325.2	298.0	330.6	296.2
S.Em ±	7.18	6.46	7.21	6.76	7.54	5.20
CD (p=0.05)	20.74	18.65	20.83	19.52	21.78	15.03
Fertigation levels (L)						
L ₁	290.4	266.1	304.8	280.5	310.1	283.1
L ₂	292.5	269.7	308.0	282.5	313.0	284.8
L ₃	295.6	272.1	311.0	285.2	316.3	287.5
S.Em ±	5.56	5.00	5.59	5.24	5.84	4.03
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D ₁ L ₁	277.1	246.1	288.6	267.4	292.7	270.7
D ₁ L ₂	279.1	250.8	291.2	270.6	296.0	273.6
D ₁ L ₃	281.6	253.1	292.6	271.1	300.0	276.0
D ₂ L ₁	283.6	254.9	294.3	273.3	302.5	278.4
D ₂ L ₂	284.3	258.4	296.7	274.4	304.1	279.2
D ₂ L ₃	286.0	261.5	300.8	277.1	308.2	281.2
D ₃ L ₁	288.1	266.5	304.7	279.4	310.1	282.8
D ₃ L ₂	290.7	269.6	309.5	280.2	313.3	285.7
D ₃ L ₃	293.7	274.0	312.1	283.0	315.6	287.8
D ₄ L ₁	296.5	276.8	315.8	288.4	317.7	289.9
D ₄ L ₂	297.8	280.7	317.6	290.3	320.1	290.2
D ₄ L ₃	303.3	281.8	319.6	291.6	325.2	292.9
D ₅ L ₁	306.9	286.3	320.6	294.0	327.7	293.7
D ₅ L ₂	310.3	289.0	324.8	296.9	331.6	295.4
D ₅ L ₃	313.4	290.4	330.1	303.0	332.5	299.5
Control	265.3	233.3	273.3	256.3	281.4	259.1
S.Em ±	12.44	11.19	12.49	11.71	13.06	9.13
CD (p=0.05)	35.93	32.31	36.08	33.81	37.73	26.37

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Table 4.1.2a: Number of tillers m⁻¹ of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	60 DAP		120 DAP		180 DAP	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	14.21	22.34	23.19	32.72	26.62	36.19
D₂	13.99	21.99	22.52	31.62	27.47	36.72
D₃	13.76	21.61	22.00	31.10	27.98	37.35
D₄	13.53	21.24	21.59	30.46	28.50	37.92
D₅	13.34	20.80	21.01	30.09	28.98	38.77
S.Em ±	0.34	0.54	0.30	0.29	0.61	0.74
CD (p=0.05)	NS	NS	0.87	0.84	1.76	2.14
Fertigation levels (L)						
L₁	13.69	21.47	21.87	30.89	27.65	37.06
L₂	13.76	21.58	22.03	31.29	27.89	37.33
L₃	13.85	21.74	22.29	31.40	28.19	37.78
S.Em ±	0.26	0.42	0.23	0.22	0.47	0.57
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	14.13	22.22	22.87	32.02	26.14	35.68
D₁L₂	14.21	22.35	23.10	32.75	26.64	36.20
D₁L₃	14.30	22.46	23.60	33.38	27.08	36.71
D₂L₁	13.90	21.87	22.39	31.46	27.21	36.56
D₂L₂	13.98	21.93	22.51	31.60	27.44	36.72
D₂L₃	14.08	22.16	22.66	31.81	27.74	36.88
D₃L₁	13.69	21.50	21.88	30.91	27.81	37.03
D₃L₂	13.76	21.57	21.97	31.13	27.93	37.43
D₃L₃	13.83	21.75	22.16	31.25	28.21	37.58
D₄L₁	13.43	21.10	21.47	30.54	28.30	37.72
D₄L₂	13.51	21.25	21.60	30.69	28.52	37.91
D₄L₃	13.64	21.38	21.71	30.13	28.67	38.14
D₅L₁	13.28	20.68	20.76	29.54	28.77	38.30
D₅L₂	13.36	20.80	20.97	30.27	28.92	38.40
D₅L₃	13.39	20.93	21.31	30.46	29.26	39.62
Control	12.12	18.04	17.14	25.01	22.04	30.31
S.Em ±	0.59	0.94	0.52	0.50	1.06	1.29
CD (p=0.05)	NS	NS	1.51	1.45	3.06	3.71

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

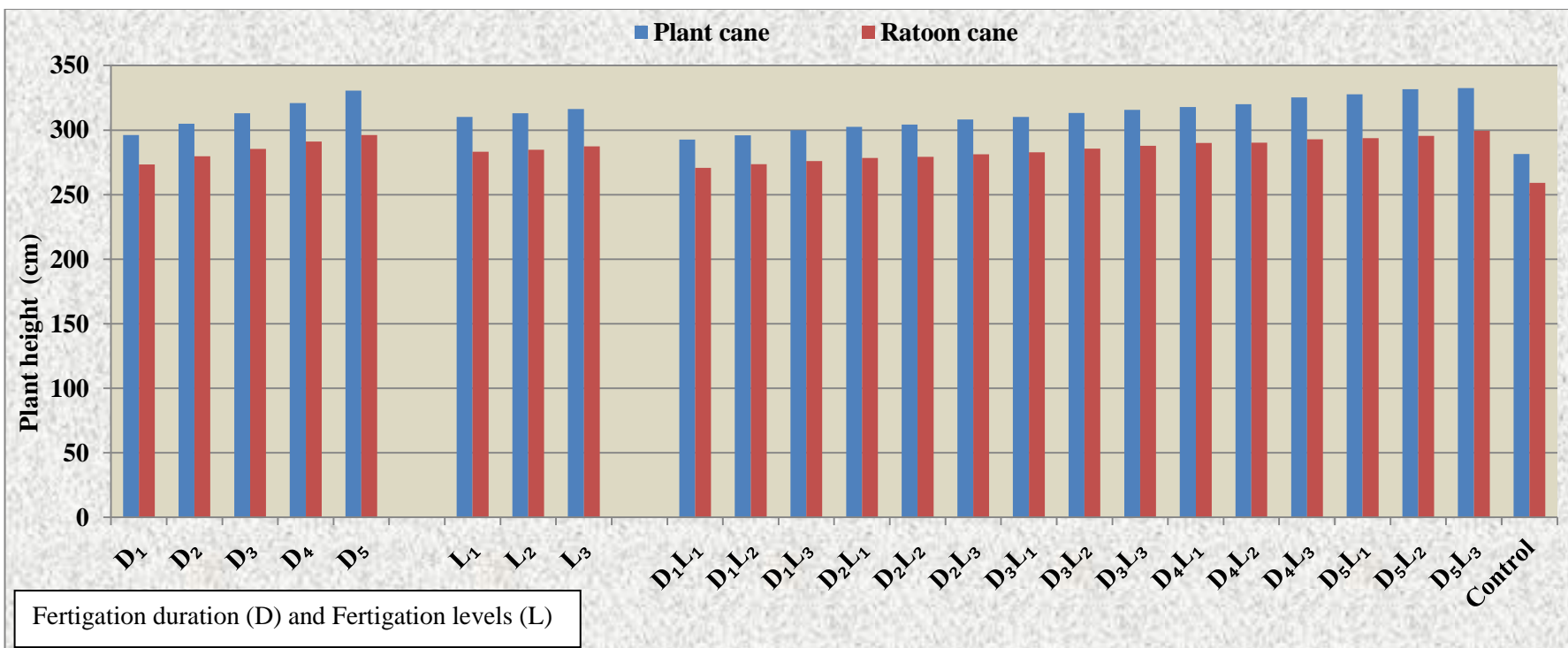
Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)



Note:

Factor A:

Fertigation duration

- D₁: Fertigation up to 3.5 months
- D₂: Fertigation up to 5.0 months
- D₃: Fertigation up to 6.5 months
- D₄: Fertigation up to 8.0 months
- D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

- L₁: 75% RDF
- L₂: 100% RDF
- L₃: 125% RDF
- Control: Soil application of 100% RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.1: Plant height (cm) of plant and ratoon cane at harvest as influenced by fertigation duration and levels

Table 4.1.2b: Number of tillers m⁻¹ of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	240 DAP		300 DAP		At harvest	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	30.59	40.41	33.04	41.70	33.34	41.52
D₂	31.25	40.95	33.93	42.48	33.71	41.90
D₃	31.69	41.46	33.91	42.73	33.98	42.30
D₄	32.27	42.16	34.46	42.98	34.21	42.77
D₅	32.93	42.98	34.98	43.52	34.66	43.33
S.Em ±	0.63	0.68	0.57	0.59	0.36	0.57
CD (p=0.05)	1.81	1.97	1.65	1.72	1.04	1.65
Fertigation levels (L)						
L₁	31.49	41.33	33.74	42.43	33.82	42.14
L₂	31.75	41.53	34.10	42.67	33.98	42.32
L₃	32.00	41.91	34.35	42.95	34.14	42.63
S.Em ±	0.49	0.53	0.44	0.46	0.28	0.44
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	30.13	40.06	32.41	41.00	33.00	41.11
D₁L₂	30.72	40.55	33.26	41.80	33.47	41.66
D₁L₃	30.93	40.63	33.45	42.29	33.54	41.79
D₂L₁	31.10	40.75	33.70	42.39	33.60	41.83
D₂L₂	31.26	40.91	33.96	42.47	33.72	41.91
D₂L₃	31.40	41.19	34.15	42.58	33.82	41.96
D₃L₁	31.53	41.29	33.53	42.65	33.90	42.15
D₃L₂	31.65	41.38	33.96	42.73	33.97	42.24
D₃L₃	31.91	41.71	34.24	42.80	34.07	42.52
D₄L₁	32.10	41.97	34.34	42.90	34.12	42.65
D₄L₂	32.27	42.07	34.43	42.98	34.21	42.77
D₄L₃	32.44	42.44	34.61	43.07	34.32	42.89
D₅L₁	32.61	42.59	34.72	43.20	34.47	42.95
D₅L₂	32.86	42.76	34.90	43.36	34.55	43.05
D₅L₃	33.31	43.57	35.31	44.00	34.97	43.98
Control	25.53	34.70	27.45	38.51	29.20	38.15
S.Em ±	1.09	1.18	0.99	1.03	0.62	0.99
CD (p=0.05)	3.14	3.41	2.86	2.98	1.80	2.86

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

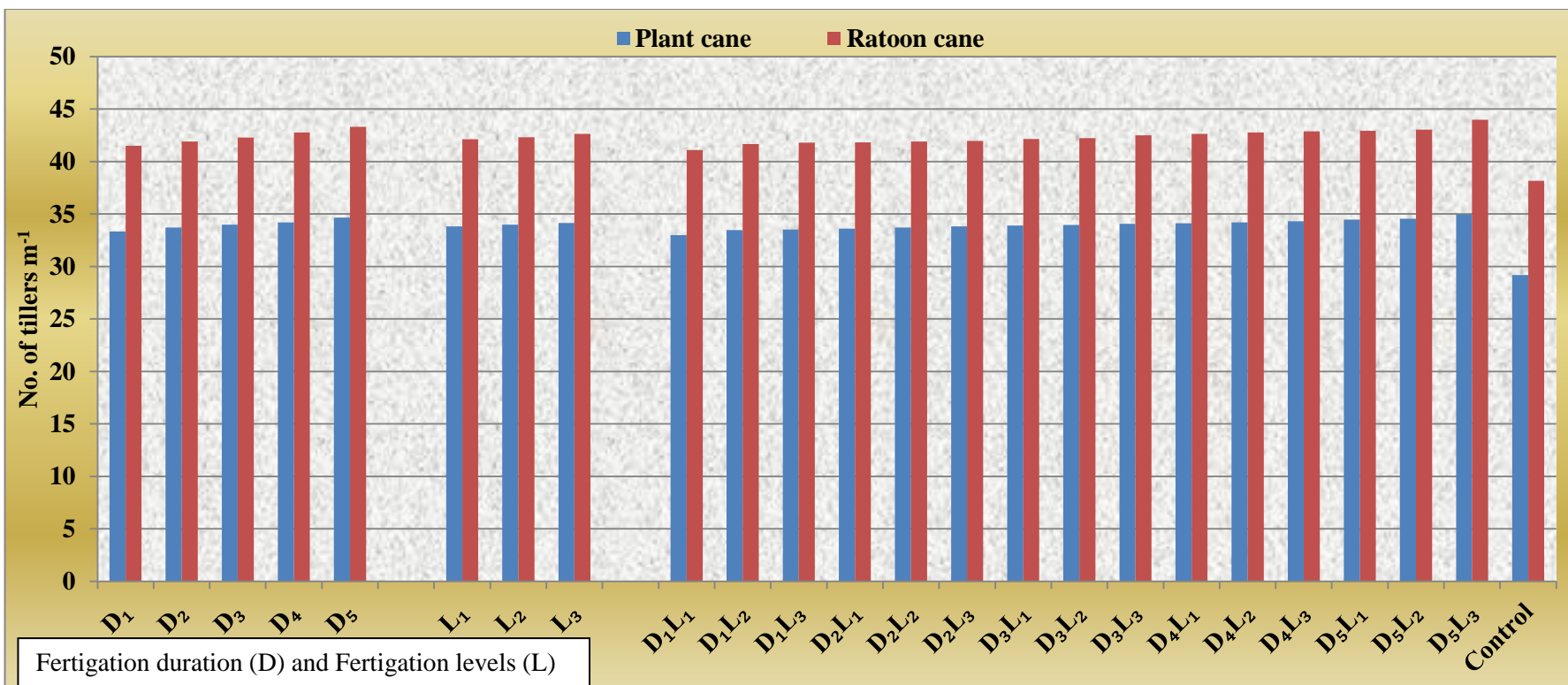
Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Drip fertigation duration and fertigation levels showed significant difference at early and later stages of crop growth both in plant and ratoon cane. Drip fertigation upto 3.5 months with 125 per cent RDF recorded higher number of tillers m^{-1} at 60 DAP (14.30 and 22.46) in plant and ratoon cane. Numerically lower number of tillers m^{-1} was recorded with drip fertigation upto 3.5 months with 75 and 100 per cent RDF. Significantly higher number of tillers m^{-1} was noticed at 120 DAP in plant and ratoon cane with drip fertigation upto 3.5 months with 125 per cent RDF (23.60 and 33.38), on par results were observed with 100 per cent RDF (23.10 and 32.75) and with 75 per cent RDF (22.87 and 32.02) in plant and ratoon cane. Drip fertigation upto 5 months with 75, 100 and 125 per cent RDF did not influence significantly on the number of tillers m^{-1} . However, at 180, 240, 300 DAP and at harvest significant difference in number of tillers m^{-1} was observed with drip fertigation duration upto 9.5 months with 125 per cent RDF through drip fertigation (29.26 and 39.62, 33.31 and 43.57, 35.31 and 44.0, 34.97 and 43.98, respectively). This was on par with drip fertigation upto 9.5 months with 100 per cent RDF (28.92 and 38.40, 32.86 and 42.76, 34.90 and 43.36, 34.55 and 43.05, respectively) and with 75 per cent RDF (28.77 and 38.30, 32.61 and 42.59, 34.72 and 43.20, 34.47 and 42.95, respectively). Lower number of tillers m^{-1} was recorded with 60 DAP (12.12 and 18.04). Significantly, lower number of tillers m^{-1} was recorded at 120, 180, 240, 300 DAP and at harvest in surface irrigation with application of 100 per cent RDF (17.14 and 25.01, 22.04 and 30.31, 25.53 and 34.70, 27.45 and 38.51, 29.20 and 38.15, respectively).

Generally, tillering was high in all the subsurface drip fertigation treatments compared to surface irrigation method. This was mainly due to early vigorous growth of cane with the availability of required quantity of water and nutrients at the early stages compared to soil application of fertilizers wherein the fluctuation in nutrient availability is very wide (Gouthaman, 1997). Favourable moisture availability under subsurface drip irrigation enhanced the nutrient uptake and favoured for good tiller production. The results are in conformity with the findings of Sharma and Gupta (1991), Chandrashekar (2009) and Nadagouda (2011).

4.1.3 Leaf area (dm^2) (Table 4.1.3a and 4.1.3b)

Leaf area did not differ significantly at 60 DAP due to fertigation duration and fertigation levels. However, drip fertigation upto 3.5 months with 75 per cent RDF recorded higher leaf area at 60 DAP (53.29 and 67.75) and significantly higher leaf area at 120 DAP (81.90 and 105.51) in plant and ratoon cane. Drip fertigation upto 9.5 months recorded significantly higher leaf area at 180, 240, 300 DAP and at harvest (115.89 and 142.88, 125.76 and 157.71, 87.32 and 118.69, 78.80 and 96.95, respectively) as compared to other drip fertigation treatments upto 3.5, 5.0 and 6.5 months except drip fertigation upto 8 months where in the leaf area recorded was 109.19 and 137.98, 117.67 and 149.47, 81.55 and 111.64, 73.86 and 90.9, respectively which was on par with drip fertigation upto 9.5 months.



Note:

Factor A:

Fertilization duration

D₁: Fertilization up to 3.5 months
 D₂: Fertilization up to 5.0 months
 D₃: Fertilization up to 6.5 months
 D₄: Fertilization up to 8.0 months
 D₅: Fertilization up to 9.5 months

Factor B:

Fertilization levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100% RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.2: Number of tillers m⁻¹ of plant and ratoon cane at harvest as influenced by fertilization duration and levels

Table 4.1.3a: Leaf area ($\text{dm}^2 \text{ m}^{-1}$) of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	60 DAP		120 DAP		180 DAP	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	53.29	67.75	81.90	105.51	91.26	118.76
D₂	53.03	67.17	75.60	100.00	96.21	124.95
D₃	52.55	66.85	70.20	95.08	102.00	131.55
D₄	51.91	66.44	64.28	90.39	109.19	137.98
D₅	51.03	65.72	60.45	85.19	115.89	142.88
S.Em ±	0.82	1.25	2.53	3.01	2.58	2.61
CD (p=0.05)	NS	NS	7.30	8.70	7.44	7.53
Fertigation levels (L)						
L₁	52.07	66.60	68.64	93.27	100.92	129.45
L₂	52.45	66.81	70.39	95.26	102.86	131.13
L₃	52.57	66.95	72.43	97.17	104.96	133.10
S.Em ±	0.64	0.96	1.96	2.33	2.00	2.02
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	53.23	67.55	79.93	103.19	89.48	117.63
D₁L₂	53.29	67.79	81.93	105.15	91.82	118.17
D₁L₃	53.34	67.90	83.86	108.19	92.49	120.48
D₂L₁	52.95	67.03	73.19	98.15	94.49	123.78
D₂L₂	53.05	67.18	75.04	100.56	96.52	124.19
D₂L₃	53.11	67.31	78.56	101.30	97.63	126.89
D₃L₁	52.37	66.74	68.23	93.30	99.41	128.75
D₃L₂	52.58	66.88	70.34	95.26	101.63	131.93
D₃L₃	52.72	66.93	72.04	96.67	104.97	133.97
D₄L₁	51.79	66.19	62.75	87.94	107.15	136.19
D₄L₂	51.90	66.45	64.19	90.40	108.33	138.15
D₄L₃	52.04	66.69	65.91	92.82	112.10	139.60
D₅L₁	50.03	65.50	59.12	83.78	114.04	140.89
D₅L₂	51.41	65.75	60.47	84.92	116.00	143.19
D₅L₃	51.64	65.90	61.76	86.88	117.63	144.56
Control	47.67	59.27	55.70	78.75	83.38	110.30
S.Em ±	1.43	2.16	4.38	5.22	4.46	4.51
CD (p=0.05)	NS	NS	12.64	15.07	12.89	13.04

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Table 4.1.3b: Leaf area (dm² m⁻¹) of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	240 DAP		300 DAP		At harvest	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	99.67	130.23	68.09	94.60	61.74	77.02
D₂	105.72	135.83	72.78	99.88	64.91	81.82
D₃	110.92	142.19	77.38	105.82	68.99	85.74
D₄	117.67	149.47	81.55	111.64	73.86	90.92
D₅	125.76	157.71	87.32	118.69	78.80	96.95
S.Em ±	3.05	4.88	4.38	3.36	2.46	4.17
CD (p=0.05)	8.82	14.08	12.65	9.70	7.11	12.05
Fertigation levels (L)						
L₁	109.71	140.86	75.48	104.13	68.39	84.53
L₂	111.76	142.85	77.66	105.86	69.57	86.39
L₃	114.37	145.55	79.13	108.39	71.02	88.55
S.Em ±	2.37	3.78	3.39	2.60	1.91	3.23
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	98.17	128.36	65.96	93.16	60.49	75.01
D₁L₂	99.60	129.38	68.04	94.20	61.32	76.82
D₁L₃	101.26	132.94	70.25	96.45	63.40	79.23
D₂L₁	103.56	133.89	71.33	97.86	63.93	80.47
D₂L₂	105.93	135.26	72.59	99.12	64.76	81.75
D₂L₃	107.68	138.34	74.41	102.67	66.03	83.24
D₃L₁	108.89	140.72	75.86	104.26	67.70	84.34
D₃L₂	110.78	141.85	77.70	105.23	68.93	85.09
D₃L₃	113.09	144.01	78.58	107.97	70.34	87.78
D₄L₁	114.45	146.28	79.29	109.78	72.08	88.27
D₄L₂	116.81	150.15	82.23	111.89	73.90	90.96
D₄L₃	121.74	152.00	83.14	113.25	75.60	93.52
D₅L₁	123.49	155.06	84.97	115.59	77.76	94.57
D₅L₂	125.70	157.63	87.71	118.86	78.92	97.31
D₅L₃	128.08	160.45	89.27	121.63	79.71	98.97
Control	90.60	118.56	57.34	84.38	48.34	64.30
S.Em ±	5.29	8.45	7.59	5.82	4.27	7.23
CD (p=0.05)	15.28	24.39	21.91	16.81	12.32	20.88

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

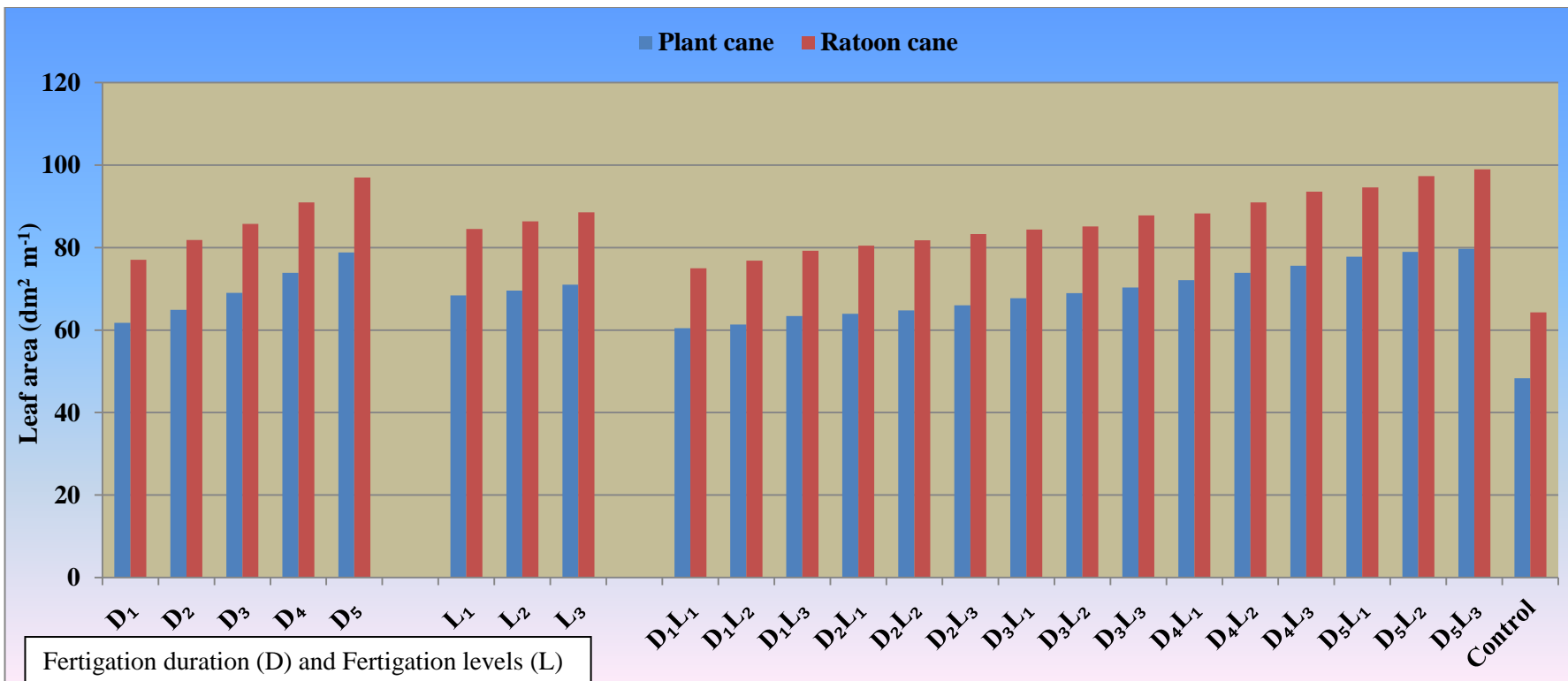
Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)



Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months
 D₂: Fertigation up to 5.0 months
 D₃: Fertigation up to 6.5 months
 D₄: Fertigation up to 8.0 months
 D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100% RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.3: Leaf area (dm² m⁻¹) of plant and ratoon cane at harvest as influenced by fertigation duration and levels

Leaf area did not differ significantly due to fertigation levels irrespective of growth stages.

Significant difference was observed with drip fertigation duration and fertigation levels. However, significant difference was observed during later stages of crop growth both in plant and ratoon cane. Drip fertigation upto 3.5 months with 125 per cent RDF recorded higher leaf area at 60 DAP (53.34 and 67.90) in plant and ratoon cane. Lower leaf area was recorded with drip fertigation upto 3.5 months with 75 and 100 per cent RDF. Significantly higher leaf area was observed at 120 DAP in plant and ratoon cane with drip fertigation upto 3.5 months with 125 per cent RDF (83.86 and 108.19) and was on par with drip fertigation upto 3.5 months with 100 per cent RDF (81.93 and 105.15) and 75 per cent RDF (79.93 and 103.19). Leaf area did not differ significantly with drip fertigation upto 5 months with 75, 100 and 125 per cent RDF. However, significant differences in leaf area was observed with drip fertigation duration upto 9.5 months with 125 per cent RDF through drip fertigation (117.63 and 144.56, 128.08 and 160.45, 89.27 and 121.63, 79.71 and 98.97, respectively) at 180, 240, 300 DAP and at harvest. This was on par with drip fertigation upto 9.5 months with 100 per cent RDF (116.0 and 143.19, 125.70 and 157.63, 87.71 and 118.86, 78.92 and 97.31, respectively) and 75 per cent RDF (114.04 and 140.89, 123.49 and 155.06, 84.97 and 115.59, 77.76 and 94.57, respectively). At 60 DAP lower leaf area (47.67 and 59.27) was recorded and statistically lower leaf area was recorded irrespective of growth stages with conventional irrigation with application of 100 per cent RDF (55.70 and 78.75, 83.38 and 110.30, 90.60 and 118.56, 57.34 and 84.38, 48.34 and 64.30, respectively).

The photosynthetic activity of plant largely depends upon leaf area. In drip irrigation required availability of water and nutrients through out the crop period matching with the crop demand helped the photosynthetic area to develop and remain active for longer period and was responsible for overall growth of plant (Kwong *et al.*, 1999). Geethalakshmi *et al.* (2011) reported that subsurface drip fertigation recorded higher plant height which helped for better utilization of solar radiation resulting in higher leaf area.

4.1.4 Leaf area index (Table 4.1.4a and 4.1.4b)

Duration of fertigation did not influence the leaf area index at 60 DAP. Whereas, at later stages significant difference was noticed. However, drip fertigation upto 9.5 months recorded significantly higher leaf area index at 180, 240, 300 DAP and at harvest (5.94 and 7.33, 6.45 and 8.09, 4.48 and 6.09, 4.04 and 4.97, respectively) as compared to other drip fertigation treatments upto 3.5, 5.0 and 6.5 months except drip fertigation upto 8 months (5.60 and 7.08, 6.03 and 7.67, 4.18 and 5.73, 3.79 and 4.66, respectively) and was on par with drip fertigation upto 9.5 months.

Increased level of fertigation levels increased the leaf area index irrespective of growth stages.

Significant difference in leaf area index was not noticed with respect to interaction effect of fertigation duration and fertigation levels at 60 DAP.

Significantly higher leaf area index was observed at 120 DAP in plant and ratoon cane with drip fertigation upto 3.5 months with 125 per cent RDF (4.30 and 5.55) and was on par with drip fertigation upto 3.5 months with 100 per cent RDF (4.20 and 5.39) and with 75 per cent RDF (4.10 and 5.29). Leaf area index did not differ significantly with drip fertigation upto 5 months with 75, 100 and 125 per cent RDF irrespective of growth stages. However, significant difference in leaf area index was observed with drip fertigation duration upto 9.5 months with 125 per cent RDF through drip fertigation (6.03 and 7.41, 6.57 and 8.23, 4.58 and 6.24, 4.09 and 5.08), respectively at 180, 240, 300 DAP and at harvest. Which was on par with drip fertigation upto 9.5 months with 100 per cent RDF (5.95 and 7.34, 6.45 and 8.08, 4.50 and 6.10, 4.05 and 4.99, respectively) and with 75 per cent RDF (5.85 and 7.23, 6.33 and 7.95, 4.36 and 5.93, 3.99 and 4.85, respectively). Lower leaf area index was recorded at 60 DAP (2.44 and 3.04) and statistically significant lower leaf area index was recorded irrespective of growth stages with conventional method of sugarcane cultivation (2.86 and 4.04, 4.28 and 5.66, 4.65 and 6.08, 2.94 and 4.33, 2.48 and 3.30, respectively).

Leaf area index is the ratio of leaf area to land area. The higher leaf area index observed in the best treatments was due to superior leaf area recorded in those treatments. Hebbar *et al.* (2004) reported that water soluble fertilizer through fertigation recorded significantly higher LAI under drip irrigation. These results are in line with the findings of Sammis and Wilkam, (2006) who observed that under drip fertigation due to availability of moisture and nutrient supply, higher value of stomatal conductance and transpiration rates, were recorded which led to increase in LAI.

4.1.5 Total dry matter production (g plant⁻¹) (Table 4.1.5a and 4.1.5b)

Total dry matter production was found to be non significant under fertigation duration at 60 DAP and fertigation levels irrespective of growth stages. Higher total dry matter production was recorded with drip fertigation upto 3.5 months at 60 DAP (28.19 and 23.59) and significantly higher total dry matter production was recorded at 120 DAP (167.94 and 113.30) in plant and ratoon cane compared to other growth stages. Significantly, higher total dry matter production was recorded with drip fertigation upto 9.5 months at 180, 240, 300 DAP and at harvest (303.85 and 241.63, 529.07 and 365.52, 623.61 and 440.78, 652.57 and 466.91, respectively) as compared to other drip fertigation treatments upto 3.5, 5.0 and 6.5 months except drip fertigation upto 8 months (289.08 and 228.85, 512.57 and 347.68, 603.23 and 424.57, 631.85 and 448.96, respectively) which was on par with drip fertigation upto 9.5 months.

Total dry matter production did not differ significantly due to fertigation levels irrespective of growth stages.

Table 4.1.4a: Leaf area index of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	60 DAP		120 DAP		180 DAP	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	2.73	3.47	4.20	5.41	4.68	6.09
D₂	2.72	3.44	3.88	5.13	4.93	6.41
D₃	2.70	3.43	3.60	4.88	5.23	6.75
D₄	2.66	3.41	3.30	4.64	5.60	7.08
D₅	2.62	3.37	3.10	4.37	5.94	7.33
S.Em ±	0.04	0.06	0.13	0.15	0.13	0.11
CD (p=0.05)	NS	NS	0.37	0.45	0.38	0.33
Fertigation levels (L)						
	L₁	L₂	L₃	S.Em ±	CD (p=0.05)	
	2.67	3.42	3.52	4.78	5.18	6.64
	2.69	3.43	3.61	4.89	5.27	6.72
	2.70	3.43	3.71	4.98	5.38	6.83
	0.03	0.05	0.10	0.12	0.10	0.09
	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	2.73	3.46	4.10	5.29	4.59	6.03
D₁L₂	2.73	3.48	4.20	5.39	4.71	6.06
D₁L₃	2.74	3.48	4.30	5.55	4.74	6.18
D₂L₁	2.72	3.44	3.75	5.03	4.85	6.35
D₂L₂	2.72	3.45	3.85	5.16	4.95	6.37
D₂L₃	2.72	3.45	4.03	5.19	5.01	6.51
D₃L₁	2.69	3.42	3.50	4.78	5.10	6.60
D₃L₂	2.70	3.43	3.61	4.89	5.21	6.77
D₃L₃	2.70	3.43	3.69	4.96	5.38	6.87
D₄L₁	2.66	3.39	3.22	4.51	5.50	6.98
D₄L₂	2.66	3.41	3.29	4.64	5.56	7.08
D₄L₃	2.67	3.42	3.38	4.76	5.75	7.16
D₅L₁	2.57	3.36	3.03	4.30	5.85	7.23
D₅L₂	2.64	3.37	3.10	4.35	5.95	7.34
D₅L₃	2.65	3.38	3.17	4.46	6.03	7.41
Control	2.44	3.04	2.86	4.04	4.28	5.66
S.Em ±	0.07	0.11	0.22	0.27	0.23	0.20
CD (p=0.05)	NS	NS	0.65	0.77	0.66	0.57

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Table 4.1.4b: Leaf area index of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation.

Treatments	240 DAP		300 DAP		At harvest	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	5.11	6.68	3.49	4.85	3.17	3.95
D₂	5.42	6.97	3.73	5.12	3.33	4.20
D₃	5.69	7.29	3.97	5.43	3.54	4.40
D₄	6.03	7.67	4.18	5.73	3.79	4.66
D₅	6.45	8.09	4.48	6.09	4.04	4.97
S.Em ±	0.16	0.25	0.22	0.17	0.13	0.21
CD (p=0.05)	0.45	0.72	0.65	0.50	0.36	0.62
Fertigation levels (L)						
L₁	5.63	7.22	3.87	5.34	3.51	4.33
L₂	5.73	7.33	3.98	5.43	3.57	4.43
L₃	5.87	7.46	4.06	5.56	3.64	4.54
S.Em ±	0.12	0.19	0.17	0.13	0.10	0.17
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	5.03	6.58	3.38	4.78	3.10	3.85
D₁L₂	5.11	6.63	3.49	4.83	3.14	3.94
D₁L₃	5.19	6.82	3.60	4.95	3.25	4.06
D₂L₁	5.31	6.87	3.66	5.02	3.28	4.13
D₂L₂	5.43	6.94	3.72	5.08	3.32	4.19
D₂L₃	5.52	7.09	3.82	5.26	3.39	4.27
D₃L₁	5.58	7.22	3.89	5.35	3.47	4.33
D₃L₂	5.68	7.27	3.98	5.40	3.53	4.36
D₃L₃	5.80	7.39	4.03	5.54	3.61	4.50
D₄L₁	5.87	7.50	4.07	5.63	3.70	4.53
D₄L₂	5.99	7.70	4.22	5.74	3.79	4.66
D₄L₃	6.24	7.79	4.26	5.81	3.88	4.80
D₅L₁	6.33	7.95	4.36	5.93	3.99	4.85
D₅L₂	6.45	8.08	4.50	6.10	4.05	4.99
D₅L₃	6.57	8.23	4.58	6.24	4.09	5.08
Control	4.65	6.08	2.94	4.33	2.48	3.30
S.Em ±	0.27	0.43	0.39	0.30	0.22	0.37
CD (p=0.05)	0.78	1.25	1.12	0.86	0.63	1.07

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)

Table 4.1.5a: Total dry matter production (g plant⁻¹) of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	60 DAP		120 DAP		180 DAP	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	28.19	23.59	165.08	113.30	248.20	191.64
D₂	27.87	23.40	157.94	105.17	260.72	203.03
D₃	27.67	23.14	149.07	97.32	274.28	216.50
D₄	27.44	22.87	140.10	90.08	289.08	228.85
D₅	27.13	22.66	131.00	83.42	303.85	241.63
S.Em ±	0.78	0.46	4.09	3.03	7.87	5.41
CD (p=0.05)	NS	NS	11.82	8.75	22.73	15.62
Fertigation levels (L)						
L₁	27.55	23.06	146.45	95.61	270.86	211.72
L₂	27.67	23.14	148.42	97.88	275.38	216.83
L₃	27.76	23.21	151.05	100.08	279.44	220.44
S.Em ±	0.61	0.35	3.17	2.35	6.10	4.19
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	28.05	23.55	163.11	110.44	245.52	189.52
D₁L₂	28.19	23.59	165.13	114.46	248.03	192.36
D₁L₃	28.33	23.63	167.00	115.00	251.05	193.05
D₂L₁	27.79	23.33	154.78	102.45	256.07	197.41
D₂L₂	27.86	23.40	158.30	104.63	261.81	203.07
D₂L₃	27.95	23.48	160.75	108.41	264.27	208.60
D₃L₁	27.60	23.02	146.67	95.00	270.04	211.71
D₃L₂	27.67	23.14	148.46	96.80	274.04	215.71
D₃L₃	27.74	23.26	152.09	100.15	278.75	222.08
D₄L₁	27.36	22.77	138.41	87.72	284.17	224.17
D₄L₂	27.43	22.89	139.79	90.42	288.90	229.24
D₄L₃	27.54	22.95	142.11	92.11	294.15	233.15
D₅L₁	26.95	22.61	129.26	82.43	298.47	235.81
D₅L₂	27.19	22.65	130.43	83.09	304.12	243.78
D₅L₃	27.27	22.71	133.30	84.73	308.96	245.30
Control	23.04	20.94	98.14	55.47	197.93	148.60
S.Em ±	1.36	0.79	7.09	5.25	13.63	9.37
CD (p=0.05)	NS	NS	20.47	15.15	39.37	27.06

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Table 4.1.5b: Total dry matter production (g plant⁻¹) of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	240 DAP		300 DAP		At harvest	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	470.91	303.88	553.40	380.73	580.75	397.20
D₂	484.24	317.79	569.61	394.02	596.71	415.68
D₃	497.94	331.83	586.05	410.43	614.15	433.15
D₄	512.57	347.68	603.23	424.57	631.85	448.96
D₅	529.07	365.52	623.61	440.78	652.57	466.91
S.Em ±	14.24	8.73	15.29	14.39	15.93	10.51
CD (p=0.05)	41.12	25.23	44.17	41.57	46.00	30.35
Fertigation levels (L)						
L₁	494.23	327.90	581.29	404.96	609.19	426.59
L₂	498.40	333.62	587.30	410.56	615.23	432.63
L₃	504.21	338.50	592.95	414.81	621.20	437.92
S.Em ±	11.03	6.77	11.85	11.15	12.34	8.14
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	466.96	298.30	547.31	375.31	573.41	391.75
D₁L₂	470.99	304.12	553.26	380.93	580.25	397.25
D₁L₃	474.79	309.22	559.62	385.95	588.59	402.59
D₂L₁	480.04	314.04	564.24	389.91	591.93	409.93
D₂L₂	484.45	318.12	568.99	394.96	597.56	416.89
D₂L₃	488.22	321.22	575.59	397.20	600.63	420.22
D₃L₁	494.27	326.27	581.48	405.96	607.89	425.89
D₃L₂	498.40	331.74	586.19	410.85	614.56	433.56
D₃L₃	501.15	337.48	590.49	414.49	620.01	440.01
D₄L₁	508.52	342.52	596.95	419.62	626.26	444.92
D₄L₂	511.92	347.25	603.45	425.12	631.22	448.56
D₄L₃	517.26	353.26	609.30	428.96	638.07	453.40
D₅L₁	521.37	358.37	616.44	433.98	646.48	460.48
D₅L₂	526.22	366.89	624.60	440.93	652.54	466.88
D₅L₃	539.63	371.29	629.78	447.44	658.70	473.37
Control	395.34	237.67	488.63	306.63	519.69	340.36
S.Em ±	24.66	15.13	26.49	24.93	27.59	18.20
CD (p=0.05)	71.23	43.70	76.51	72.01	79.68	52.56

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

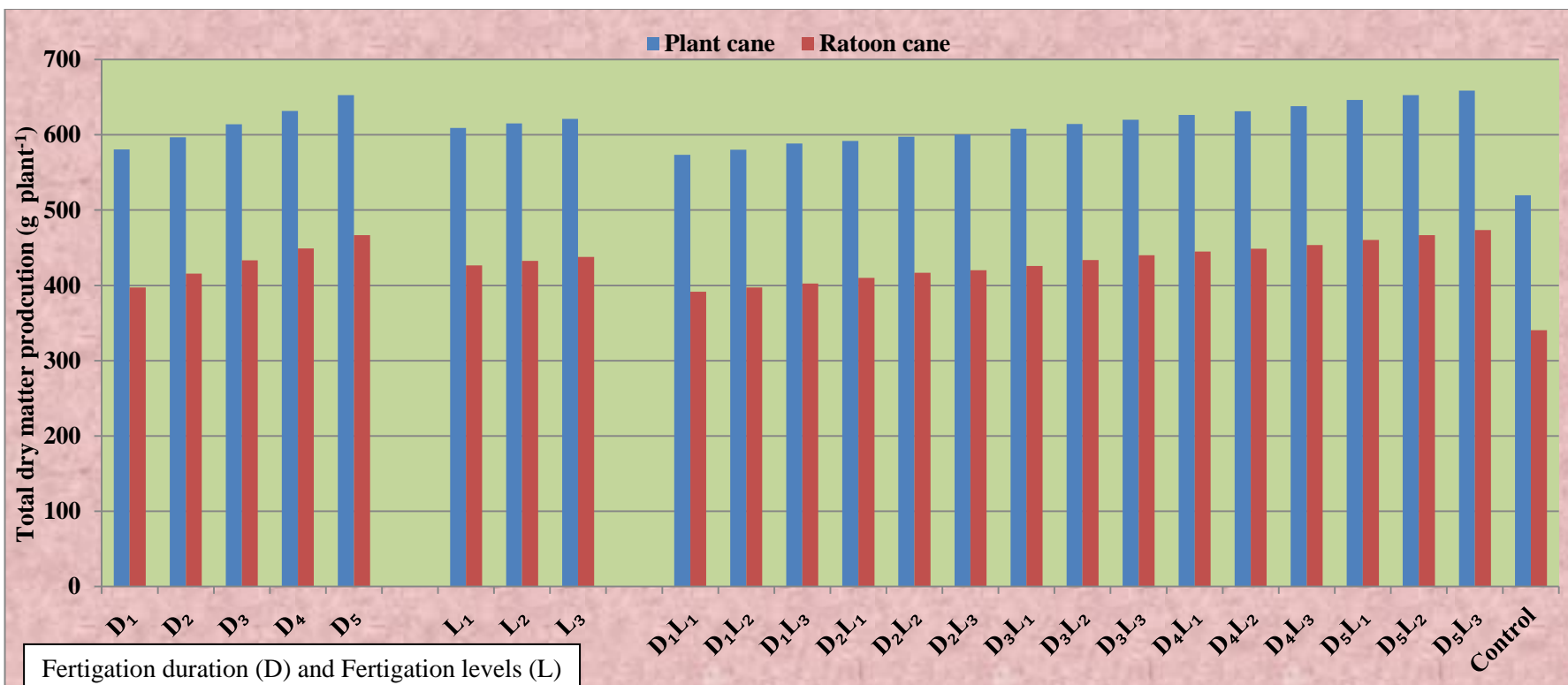
Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)



Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months
 D₂: Fertigation up to 5.0 months
 D₃: Fertigation up to 6.5 months
 D₄: Fertigation up to 8.0 months
 D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100% RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.4: Total dry matter production (g plant⁻¹) of plant and ratoon cane at harvest as influenced by fertigation duration and levels

Significant difference was observed with the interaction effect of drip fertigation duration and fertigation levels except at 60 DAP. Significantly higher total dry matter production was observed at 120 DAP in plant and ratoon cane with drip fertigation upto 3.5 months with 125 per cent RDF (167.0 and 115.0) and was on par with drip fertigation upto 3.5 months with 75 and 100 per cent RDF. Total dry matter production did not differ significantly with drip fertigation upto 5 months with 75, 100 and 125 per cent RDF. Whereas, significant differences in total dry matter production was observed with drip fertigation duration upto 9.5 months with 125 per cent RDF through drip fertigation (308.96 and 245.30, 539.63 and 371.29, 629.78 and 447.44, 658.70 and 473.37, respectively) at 180, 240, 300 DAP and at harvest and was on par with drip fertigation upto 9.5 months with 100 per cent RDF (304.12 and 243.78, 526.22 and 366.89, 624.60 and 440.93, 652.54 and 466.88, respectively) and with 75 per cent RDF (298.47 and 235.81, 521.37 and 358.37, 616.44 and 433.98, 646.48 and 460.48, respectively) in plant and ratoon cane. Significantly, lower total dry matter production was recorded at 120, 180, 240, 300 DAP and at harvest in plant and ratoon cane (98.14 and 55.47, 197.93 and 148.60, 395.34 and 237.67, 488.63 and 306.63, 519.69 and 340.36) in plant and ratoon cane respectively.

Higher DMP was mainly due to increased performance of plant characters such as plant height, tiller number, growth and physiological parameters. This favorable increase in plant characters was mainly due to higher soil moisture facilitated through subsurface drip irrigation which would have supplied the adequate quantity of water needed for the crop growth. This in turn led to increased photosynthesis resulting in higher dry matter production. Similar findings of higher DMP with increasing duration of fertigation was reported by Dhanalakshmi (1999) and Mahendran *et al.* (2005). This might be due to increased availability and uptake of water soluble nutrients from water soluble fertilizers. This favorable increase in plant characteristics was mainly due to the enhanced availability of nutrients by the continuous and split supply of nutrients along with the required quantity of water needed for the crop growth stages in sugarcane. Similar result were reported by Mahesh (2009) in double side planting of cane under subsurface drip fertigation system. Subramani (2008) reported that drip fertigation of 100 per cent RDF as water soluble fertilizer based on the crop growth stage resulted in an increased DMP.

4.1.6 SPAD reading (Table 4.1.6)

Significant difference was observed with fertigation duration and fertigation levels in SPAD reading. Drip fertigation upto 3.5 months recorded significantly higher SPAD reading in plant and ratoon cane at 120 DAP (19.40 and 20.54). Significantly higher SPAD reading was observed with drip fertigation upto 9.5 months in plant and ratoon cane at 240 DAP (34.67 and 37.72) and at harvest (15.96 and 16.54). However, drip fertigation upto 8.0 months recorded on par results at 240 DAP (33.10 and 35.87) and at harvest (15.33 and 15.95).

Drip fertigation level did not influence the SPAD readings irrespective of growth stages.

Table 4.1.6: SPAD readings of plant and ratoon sugarcane at different days after planting as influenced by duration and levels of fertigation

Treatments	120 DAP		240 DAP		At harvest	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	19.40	20.54	27.21	29.98	13.09	13.77
D₂	17.32	18.78	28.74	31.29	13.84	14.52
D₃	16.55	18.03	30.34	32.85	14.51	15.45
D₄	15.97	17.35	33.10	35.87	15.33	15.95
D₅	15.48	16.80	34.67	37.72	15.96	16.54
S.Em ±	0.48	0.52	1.19	1.15	0.65	0.48
CD (p=0.05)	1.38	1.49	3.44	3.31	1.87	1.38
Fertigation levels (L)						
L₁	16.55	18.00	30.06	32.83	14.30	15.03
L₂	16.93	18.35	30.97	33.49	14.47	15.17
L₃	17.35	18.55	31.41	34.31	14.87	15.54
S.Em ±	0.37	0.40	0.92	0.89	0.50	0.37
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	18.38	19.83	26.56	29.08	12.63	13.68
D₁L₂	19.30	20.58	27.38	30.07	13.00	13.75
D₁L₃	20.52	21.20	27.71	30.80	13.63	13.89
D₂L₁	17.08	18.42	27.93	31.11	13.77	14.11
D₂L₂	17.32	18.78	28.99	31.27	13.84	14.40
D₂L₃	17.57	19.15	29.30	31.50	13.92	15.04
D₃L₁	16.31	17.94	29.61	31.65	14.16	15.25
D₃L₂	16.53	18.02	30.52	32.92	14.44	15.32
D₃L₃	16.82	18.14	30.88	33.96	14.93	15.78
D₄L₁	15.84	17.28	31.73	34.66	15.05	15.84
D₄L₂	15.98	17.61	33.33	35.49	15.13	15.96
D₄L₃	16.10	17.15	34.24	37.45	15.82	16.04
D₅L₁	15.14	16.53	34.47	37.64	15.89	16.25
D₅L₂	15.53	16.74	34.62	37.69	15.94	16.40
D₅L₃	15.76	17.13	34.92	37.82	16.06	16.96
Control	13.05	14.22	23.39	26.47	11.05	12.05
S.Em ±	0.83	0.89	2.07	1.99	1.12	0.83
CD (p=0.05)	2.39	2.58	5.97	5.73	3.24	2.39

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

DAP-Days after planting/Ratoon initiation

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)

Interaction effect of drip fertigation upto 3.5 months with 125 per cent RDF at 120 DAP recorded significantly higher SPAD reading in plant and ratoon cane (20.52 and 21.20) whereas on par results was observed with drip fertigation upto 3.5 months with 100per cent RDF (19.30 and 20.58) and with 75 per cent RDF (18.38 and 19.83). Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher SPAD reading in plant and ratoon cane at 240 DAP (34.92 and 37.82) and at harvest (16.06 and 16.96). However, on par results was observed with drip fertigation upto 9.5 months with 100per cent RDF (34.62 and 37.69) and at harvest (15.94 and 16.40) and with 75 per cent RDF (34.47 and 37.64) and at harvest (15.89 and 16.25). Surface irrigation with soil application of 100 per cent RDF recorded significantly lower SPAD reading in all the stages.

Aruna *et al.* (2007) observed that SPAD chlorophyll meter reading recorded at middle lamina of the third leaf from the top of millable cane registered higher SPAD reading and was mainly due to better availability of nutrients and water through out the crop period through subsurface drip irrigation.

Chlorophyll content of the leaf (SPAD values) which otherwise indicates the nitrogen status of the leaves showed maximum values upto 6 months and showed declining values when there is conversion of monosaccharides to disaccharide (sucrose). The higher values of SPAD at six months was noticed as the crop was in grand growth phase and quite efficient in taking up water and nutrients from the soil coupled with less of biochemical changes in the plant in conversion to saccharides from 8 to 10 months and at later stages (crop maturity), the quality parameters disintegrate through inversion and the released nitrogen within the plant may show green (higher SPAD values) under ample moisture supply (Chandrashekara 2009). Similar results was also given by Nadagouda (2011) observed SPAD readings was significant at 6 months in drip plots over the control and among the drip plots also SPAD readings differed significantly at 6 months for fertigation intervals. This indicates that the crop during its grand growth period puts up lot of vegetative growth with higher amount of chlorophyll content as all the physiological processes are active and fast changes in crop phenology are seen. With age of the crop, the bio-chemical changes get complex in nature for conversion of simple sugars to disaccharide (sucrose). Hence, the chlorophyll content of the crop gets gradually reduced with the age of the crop and eventually lower SPAD values are recorded.

Soil application of 100 per cent RDF with surface irrigation recorded significantly lower growth parameters like plant height, number of tillers m^{-1} , leaf area, leaf area index, total dry matter production and SPAD readings. This was mainly due to the inadequate supply of the required plant nutrients and irrigation water. The findings are in line with those of Kittad *et al.* (1995) who observed declined trend in tiller production when surface irrigation was adopted for fertilizer application with surface irrigation, nutrients was applied to the top soil layer. This layer was subjected to alternate drying and wetting cycles due to longer irrigation intervals. Low soil water content as well as higher fixation with soil colloids had reduced the availability of applied nutrients that led to lower uptake of nutrients by the sugarcane crop. Similar absorption pattern with varying irrigation methods was narrated by Escobar (1995).

4.2 Yield components of sugarcane

4.2.1 Number of millable canes m⁻¹ (Table 4.2.1a)

Number of millable canes (NMC) production is one of the most important characters in cane cultivation deciding the final cane yield.

Number of millable canes at harvest, drip fertigation upto 9.5 months recorded significantly higher number of millable canes m⁻¹ (26.45 and 27.47) in plant and ratoon cane. While drip fertigation upto 8.0, 6.5 and 5.0 months recorded on par results of number of millable canes m⁻¹ (25.98 and 26.98, 25.69 and 26.59, 25.23 and 25.98) in plant and ratoon cane, respectively.

Drip fertigation level did not influence number of millable canes significantly.

Interaction effect of fertigation duration and fertigation levels on number of millable canes was found to be significant. Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher NMC in plant and ratoon cane (26.67 and 27.76, respectively) and on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF (26.43 and 27.44) and with 75 per cent RDF (26.23 and 27.21) in plant and ratoon cane. Statistically on par results were observed with drip fertigation upto 8.0, 6.5 and 5.0 months *i.e.*, drip fertigation upto 8.0 months with 125 per cent RDF (26.03 and 27.11), with 100 per cent RDF (25.99 and 27.03) and with 75 per cent RDF (25.91 and 26.80). Drip fertigation upto 6.5 months with 125 per cent RDF (25.83 and 26.69), with 100 per cent RDF (25.69 and 26.57) and with 75 per cent RDF (25.57 and 26.50). Drip fertigation upto 5 months with 125 per cent RDF (25.45 and 26.14), with 100 per cent RDF (25.29 and 26.0) and with 75 per cent RDF (24.97 and 25.79) in plant and ratoon cane. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower number of NMC (21.05 and 22.85) in plant and ratoon cane.

The higher NMC production under subsurface drip fertigation systems was mainly due to the enhanced supply of plant nutrients and continuous availability of water directly to root zone of crop and without any stress. This increase in NMC was also due to better and early conversion of tillers into millable canes. Otherwise, this would have resulted in the excess production of tillers in the early stages and would have diverted the plant nutrients unnecessarily for unproductive purpose. This was better managed by the continuous and split application of the plant nutrients up to 210 DAP, which in turn helped to maintain a healthy and viable millable cane population at field level. Higher NMC could be attributed to increased level of fertigation and adequate moisture given at right time to meet the crop need at different growth stages through subsurface drip system. These results are in accordance with the findings of Ghugare and Lokesh (1994) and Mahendran *et al.* (2005) who reported that drip irrigation at 125 per cent RDF in two row planting system registered higher NMC due to higher moisture regime and also increased root activity. Jayabal (1997) reported that higher moisture regime produced higher NMC and consistently decreased in lowering irrigation regimes.

4.2.2 Cane length (m) (Table 4.2.1a)

Drip fertigation upto 9.5 months recorded significantly higher cane length at harvest (2.35 and 2.26 m) in plant and ratoon cane. Whereas, drip fertigation upto 8.0 and 6.5 months recorded on par results of cane length (2.28 and 2.20 m, 2.21 and 2.13 m).

Drip fertigation level did not influence the cane length significantly.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF at harvest recorded significantly higher cane length in plant and ratoon cane (2.37 and 2.27 m) and on par results was observed with drip fertigation upto 9.5 months with 100 per cent RDF (2.35 and 2.26) and with 75 per cent RDF (2.32 and 2.25) in plant and ratoon cane. Statistically on par results were observed with drip fertigation upto 8.0 and 6.5 months *i.e.*, drip fertigation upto 8.0 months with 125 per cent RDF (2.29 and 2.23), with 100 per cent RDF (2.28 and 2.20) and with 75 per cent RDF (2.26 and 2.16). Drip fertigation upto 6.5 months with 125 per cent RDF (2.23 and 2.15), with 100 per cent RDF (2.20 and 2.14) and with 75 per cent RDF (2.19 and 2.11) in plant and ratoon cane. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower cane length of (2.0 and 1.90 m) in plant and ratoon cane.

Higher cane length was due to the higher availability of soil moisture in the entire root zone area and higher proliferation of roots. This might be due to higher availability of plant nutrients along with higher soil moisture for early development of plant parts and rooting system, which might have enhanced more uptake of water and plant nutrients. The results of this present study were line with findings of Matheswaran (2008) who reported that yield attributing characters of sugarcane crop was higher under drip fertigation with 125 per cent RDF as water soluble fertilizer treatment. This might be due to the fact that the adequate nutrients supplied from these treatments created more conducive environment for the roots to absorb the nutrients more effectively. Similar findings was also reported by Mahendran *et al.*, (2005), Dhanalakshmi (1999), Kavitha *et al.* (2007), Sundar *et al.*, (2000) and Subramani (2008).

4.2.3 Number of internodes cane⁻¹(Table 4.2.1a)

Long internodes characterize good quality of cane and is closely associated to the yield of cane.

Number of internodes cane⁻¹ at harvest was significantly influenced by drip fertigation upto 9.5 months and recorded higher number of internodes cane⁻¹ (21.37 and 19.77) in plant and ratoon cane. However, drip fertigation upto 8.0, 6.5 and 5.0 months recorded on par results of internodes cane⁻¹ (20.76 and 19.39, 20.43 and 18.97, 20.18 and 18.61) in plant and ratoon cane, respectively.

Statistically there was no significant difference in number of internodes cane⁻¹ due to drip fertigation level.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF at harvest recorded significantly higher number of internodes cane⁻¹ in plant and ratoon cane (22.01 and 19.90). Whereas, on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF (21.10 and 19.77) and with 75 per cent RDF (21.01 and 19.65) in plant and ratoon cane. Statistically on par results were recorded with drip fertigation upto 8.0, 6.5 and 5.0 months *i.e.*, drip fertigation upto 8.0 months with 125 per cent RDF (20.89 and 19.53), with 100 per cent RDF (20.76 and 19.38) and with 75 per cent RDF (20.61 and 19.26). Drip fertigation upto 6.5 months with 125 per cent RDF (20.53 and 19.10), with 100 per cent RDF (20.43 and 18.99) and with 75 per cent RDF (20.32 and 18.83). Drip fertigation upto 5.0 months with 125 per cent RDF (20.24 and 18.74), with 100 per cent RDF (20.18 and 18.61) and with 75 per cent RDF (20.12 and 18.48). However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower number of internodes cane⁻¹ (18.97 and 16.95) in plant and ratoon cane.

Higher number of internodes cane⁻¹ was mainly due to application of water and nutrients that helps in achieving higher photosynthetic mobility resulting in thickened and long internodes (Dillewijn, 2002). The soil moisture kept above the field capacity by the frequent irrigation (once in 3 days) and nutrient supply that match with the crop growth demand along with good soil aeration throughout the crop growth period under SSDF might have favoured the faster cell division and cell elongation which ultimately resulted in higher number of internodes (Gurusamy *et al.*, 2013).

4.2.4 Cane girth (cm) (Table 4.2.1b)

The thickness of the cane is one of the yield parameters and this determines the final cane yield.

Drip fertigation upto 9.5 months at harvest recorded significantly higher cane girth (3.23 and 2.86 cm) in plant and ratoon cane. Whereas, drip fertigation upto 8.0 and 6.5 months recorded on par results of cane girth at harvest (3.16 and 2.73 cm, 3.08 and 2.67 cm) in plant and ratoon cane, respectively.

Drip fertigation level did not influence the cane girth significantly.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF at harvest recorded significantly higher cane girth in plant and ratoon cane (3.26 and 2.90 cm). Whereas, on par results was observed with drip fertigation upto 9.5 months with 100 per cent RDF (3.23 and 2.85 cm), with 75 per cent RDF (3.21 and 2.82 cm). Statistically on par results were recorded with drip fertigation upto 8.0 and 6.5 months *i.e.*, drip fertigation upto 8.0 months with 125 per cent RDF (3.19 and 2.75 cm), with 100 per cent RDF (3.16 and 2.74 cm) and with 75 per cent RDF (3.14 and 2.72 cm). Drip fertigation upto 6.5 months with 125 per cent RDF (3.11 and 2.70 cm), with 100 per cent RDF (3.08 and 2.67 cm) and with 75 per cent RDF (3.04 and 2.65 cm) in plant and ratoon cane. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower cane girth of (2.79 and 2.43 cm) in plant and ratoon cane.

Higher cane girth was mainly due to better availability of water and nutrients that helps in achieving higher photosynthetic rate resulting in higher yield parameters.

These results are in line with those of Pandian *et al.* (2009) who stated that the subsurface drip enabled the plant to absorb more soil moisture and sustain higher relative sheath moisture content by maintaining optimum available soil moisture in the root zone throughout the growth period resulting in higher growth and yield parameters. The sheath moisture could be used as an index for irrigating cane crop as soil moisture affected the sheath moisture content directly. Similar result was also reported by Chandrashekara (2009) and Nadagouda (2011).

4.2.5 Single cane weight (kg) (Table 4.2.1b)

The weight of individual millable cane is of considerable significance due to its close relation to ultimate cane yield.

Drip fertigation upto 9.5 months recorded significantly higher single cane weight of 1.70 and 1.50 kg in plant and ratoon cane, respectively. Drip fertigation upto 8.0 and 6.5 months recorded on par results of cane weight (1.61 and 1.43 kg, 1.54 and 1.37 kg) in plant and ratoon cane.

Significant difference in single cane weight was not observed due to drip fertigation level.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF at harvest recorded significantly higher single cane weight in plant and ratoon cane (1.73 and 1.55 kg). However, on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF (1.71 and 1.49 kg) and with 75 per cent RDF (1.65 and 1.47 kg). Statistically on par result were recorded with drip fertigation upto 8.0 and 6.5 months *i.e.*, drip fertigation upto 8.0 months with 125 per cent RDF (1.63 and 1.45 kg), with 100 per cent RDF (1.61 and 1.43 kg) and with 75 per cent RDF (1.58 and 1.41 kg). Drip fertigation upto 6.5 months with 125 per cent RDF (1.56 and 1.39 kg), with 100 per cent RDF (1.55 and 1.37 kg) and with 75 per cent RDF (1.52 and 1.36 kg) in plant and ratoon cane. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower single cane weight of (1.28 and 1.22 kg) in plant and ratoon cane.

The increased trend in cane weight was noticed with increased irrigation and nutrients. The increase in cane weight is due to higher availability of required quantity of water and soil moisture at root zone to meet the crop demand in the entire life cycle along with sunlight and aeration resulting to better yield attributes. These results are in conformity with findings of Mahendran *et al.* (2005) who reported that drip irrigation at 100 per cent RDF in two row planting system registered higher cane weight and cane yield which was comparable with the same method of planting at 75 per cent RDF and lower cane yield was obtained in surface irrigation method. The increase in individual cane weight was mainly due to increased individual cane length, girth and number of internodes and this favorable influence was due to more uptake of primary nutrients there by increasing the cell activities which ultimately contributed for the higher cane weight (Jayaram *et al.*, 2010).

Table 4.2.1a: Yield parameters of plant and ratoon sugarcane at harvest as influenced by duration and levels of fertigation

Treatments	No. of millable canes m ⁻¹		Cane length (m)		No. of internodes cane ⁻¹	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	24.01	24.87	2.10	2.00	19.90	17.92
D₂	25.23	25.98	2.15	2.07	20.18	18.61
D₃	25.69	26.59	2.21	2.13	20.43	18.97
D₄	25.98	26.98	2.28	2.20	20.76	19.39
D₅	26.45	27.47	2.35	2.26	21.37	19.77
S.Em ±	0.67	0.73	0.05	0.06	0.45	0.52
CD (p=0.05)	1.94	2.10	0.16	0.16	1.29	1.51
Fertigation levels (L)						
L₁	25.18	26.07	2.20	2.11	20.37	18.68
L₂	25.51	26.39	2.21	2.14	20.47	19.00
L₃	25.72	26.67	2.23	2.16	20.74	19.13
S.Em ±	0.52	0.56	0.04	0.04	0.35	0.40
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	23.22	24.05	2.08	1.97	19.77	17.16
D₁L₂	24.15	24.90	2.10	2.01	19.88	18.24
D₁L₃	24.65	25.65	2.12	2.03	20.04	18.37
D₂L₁	24.97	25.79	2.13	2.05	20.12	18.48
D₂L₂	25.29	26.00	2.14	2.07	20.18	18.61
D₂L₃	25.45	26.14	2.16	2.10	20.24	18.74
D₃L₁	25.57	26.50	2.19	2.11	20.32	18.83
D₃L₂	25.69	26.57	2.20	2.14	20.43	18.99
D₃L₃	25.83	26.69	2.23	2.15	20.53	19.10
D₄L₁	25.91	26.80	2.26	2.16	20.61	19.26
D₄L₂	25.99	27.03	2.28	2.20	20.76	19.38
D₄L₃	26.03	27.11	2.29	2.23	20.89	19.53
D₅L₁	26.23	27.21	2.32	2.25	21.01	19.65
D₅L₂	26.43	27.44	2.35	2.26	21.10	19.77
D₅L₃	26.67	27.76	2.37	2.27	22.01	19.90
Control	21.05	22.85	2.00	1.90	18.97	16.95
S.Em ±	1.16	1.26	0.09	0.10	0.77	0.90
CD (p=0.05)	3.36	3.64	0.27	0.28	2.23	2.61

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months
D₂: Fertigation up to 5.0 months
D₃: Fertigation up to 6.5 months
D₄: Fertigation up to 8.0 months
D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF
L₂: 100 % RDF
L₃: 125 % RDF
Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)

4.2.6 Cane yield (t ha^{-1}) (Table 4.2.1b)

Subsurface drip fertigation positively influenced the cane yield of sugarcane. The increased drip fertigation levels applied through subsurface drip system boosted the yield contributing parameters like number of millable canes, cane length, cane weight, cane girth and number of internodes cane^{-1} .

Significantly higher cane yield was recorded in drip fertigation upto 9.5 months (250 and 224 t ha^{-1} , respectively) in plant and ratoon cane. Whereas, drip fertigation upto 8.0 months recorded on par results of cane yield at harvest (234 and 212 t ha^{-1}).

Drip fertigation level did not influence cane yield significantly.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF at harvest recorded significantly higher cane yield in plant and ratoon cane (255 and 227 t ha^{-1}) on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF (249 and 225 t ha^{-1}) and with 75 per cent RDF (246 and 221 t ha^{-1}). Whereas, on par results were observed with drip fertigation upto 8.0 months with 125 per cent RDF (239 and 215 t ha^{-1}), with 100 per cent RDF (233 and 212 t ha^{-1}) and with 75 per cent RDF (230 and 210 t ha^{-1}) in plant and ratoon cane. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower cane yield (147 and 139 t ha^{-1}) in plant and ratoon cane.

The increase in cane yield is due to higher availability of required quantity of water and soil moisture at root zone to meet the crop demand in the entire life cycle along with sunlight and aeration resulting to better cane yield and yield attributes. These results are in conformity with findings of the Khandagave (2005) who observed that highest cane yield under subsurface drip fertigation was mainly due to the availability of adequate nutrients and water throughout the crop growth period. This favorable condition resulted in better and earlier conversion of tillers to millable canes and the early vigour was maintained throughout the crop growth period due to better survival of tillers, which in turn resulted in taller stalks and improved stalk weight at harvest. The result also revealed that fertigation of higher level of N and K under subsurface drip fertigation system enhanced the cane yield. Improvement in growth and yield attributes owing to positive influence and its efficiency and greater partitioning of metabolites as well as adequate translocation of nutrients to the developing reproductive substance led to higher yield. This result was in corroboration with the finding of Aneg Singh, (2007), Navnit Kumar and Sinha *et al.* (2008) and Jayaram *et al.* (2010).

Soil application of 100 per cent RDF with surface irrigation recorded significantly lower yield and yield parameters and was mainly due to lack of required quantity of nutrients and water at proper growth stage of the crop. This result is in line with the findings of Dalri and Cruz (2008) who stated surface method of irrigation produced the lowest cane yield and the reasons for low yield in surface irrigation might be water stress between two irrigations and lack of nutrients. Similar result was also reported by (Singh *et al.* 2010).

Table 4.2.1b: Yield parameters of plant and ratoon sugarcane at harvest as influenced by duration and levels of fertigation

Treatments	Cane girth (cm)		Single cane weight (kg)		Cane yield (t ha ⁻¹)	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	2.88	2.52	1.40	1.30	192	177
D₂	2.97	2.60	1.46	1.33	206	188
D₃	3.08	2.67	1.54	1.37	220	201
D₄	3.16	2.73	1.61	1.43	234	212
D₅	3.23	2.86	1.70	1.50	250	224
S.Em ±	0.08	0.08	0.04	0.05	6.06	5.94
CD (p=0.05)	0.24	0.22	0.11	0.15	17.50	17.15
Fertigation levels (L)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
L₁	3.03	2.65	1.51	1.37	217	197
L₂	3.06	2.68	1.55	1.38	220	200
L₃	3.10	2.71	1.57	1.41	225	204
S.Em ±	0.06	0.06	0.03	0.04	4.69	4.60
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	2.83	2.50	1.37	1.29	189	174
D₁L₂	2.88	2.52	1.41	1.30	192	176
D₁L₃	2.93	2.54	1.42	1.31	195	180
D₂L₁	2.94	2.57	1.44	1.32	201	185
D₂L₂	2.96	2.60	1.45	1.33	206	188
D₂L₃	3.01	2.63	1.49	1.34	210	192
D₃L₁	3.04	2.65	1.52	1.36	216	196
D₃L₂	3.08	2.67	1.55	1.37	219	200
D₃L₃	3.11	2.70	1.56	1.39	224	206
D₄L₁	3.14	2.72	1.58	1.41	230	210
D₄L₂	3.16	2.74	1.61	1.43	233	212
D₄L₃	3.19	2.75	1.63	1.45	239	215
D₅L₁	3.21	2.82	1.65	1.47	246	221
D₅L₂	3.23	2.85	1.71	1.49	249	225
D₅L₃	3.26	2.90	1.73	1.55	255	227
Control	2.79	2.43	1.28	1.22	147	139
S.Em ±	0.14	0.13	0.06	0.09	10.50	10.29
CD (p=0.05)	0.41	0.38	0.19	0.25	30.32	29.71

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

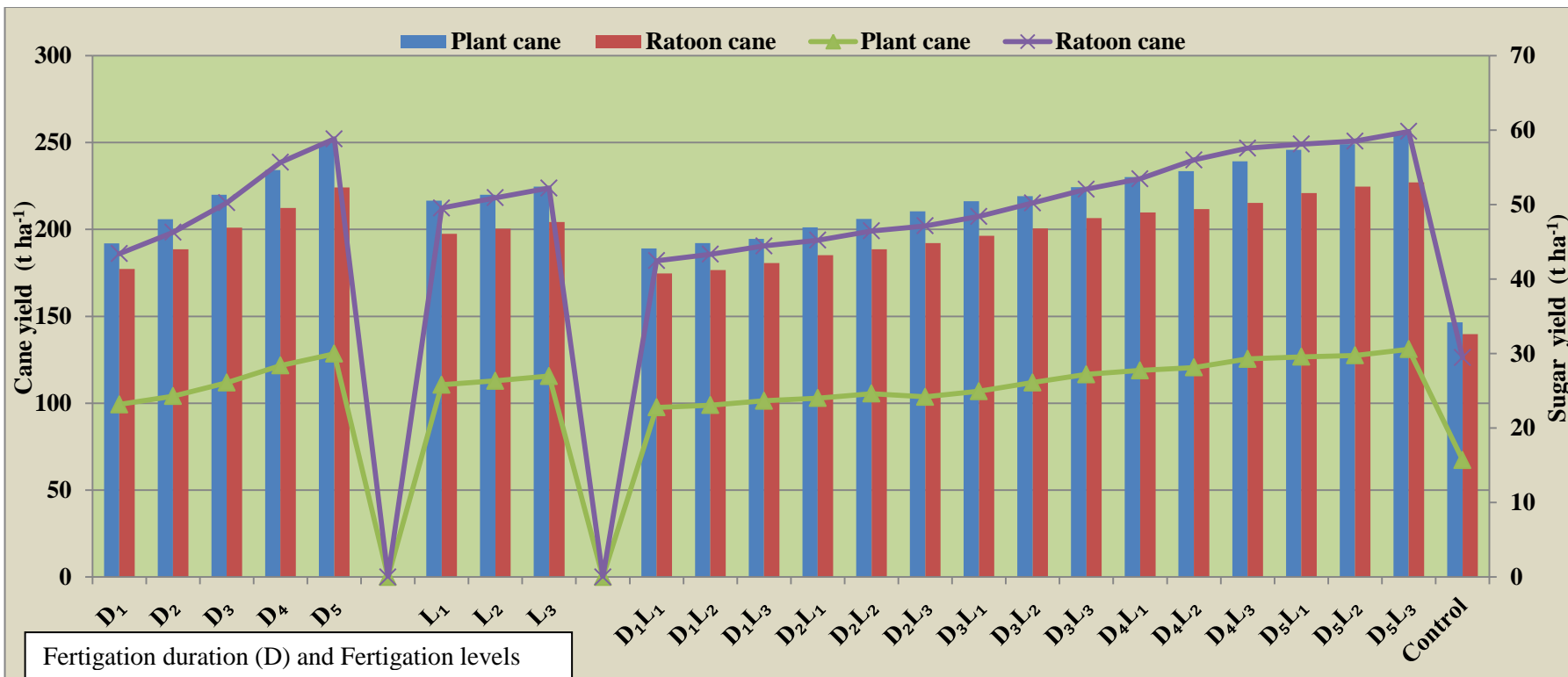
Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)



Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months
 D₂: Fertigation up to 5.0 months
 D₃: Fertigation up to 6.5 months
 D₄: Fertigation up to 8.0 months
 D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100% RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.5: Cane yield and sugar yield (t ha⁻¹) of plant and ratoon cane as influenced by fertigation duration and levels



T₁₅: Drip fertigation upto 9.5 months with 125 % RDF

Plate 6: Field view of drip fertigation upto 9.5 months with 125 % RDF



T₁₆: Soil application of 100 % RDF with surface irrigation

Plate 7: Field view of soil application of 100 % RDF with surface irrigation

4.2.7 Water productivity (t ha cm⁻¹) (Table 4.2.1c)

Drip fertigation upto 9.5 months recorded significantly higher water productivity in plant and ratoon cane (1.78 and 1.60 t ha cm⁻¹). However, on par results were observed with drip fertigation upto 8.0 months (1.67 and 1.52 t ha cm⁻¹).

Significant differences were not observed in water productivity due to drip fertigation level.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher water productivity in plant and ratoon cane (1.82 and 1.62 t ha cm⁻¹) and on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF (1.78 and 1.60 t ha cm⁻¹), with 75 per cent RDF (1.76 and 1.58 t ha cm⁻¹) in plant and ratoon cane. Statistically on par results were recorded with drip fertigation upto 8.0 months with 125 per cent RDF (1.71 and 1.54 t ha cm⁻¹), with 100 per cent RDF (1.67 and 1.51 t ha cm⁻¹) and with 75 per cent RDF (1.64 and 1.50 t ha cm⁻¹) in plant and ratoon cane. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower water productivity (1.05 and 1.00 t ha cm⁻¹) in plant and ratoon cane.

Subsurface drip fertigation is an efficient method to deliver water and nutrients to the crops because water is directly applied to the effective root zone of crop plants. The minimum loss of water resulted in the lower water requirement in subsurface drip irrigation system compared to surface irrigation. Similar findings were reported by Sankar *et al.* (2008).

Water productivity can be increased either by increasing the yield or by reducing the quantity of water applied and this could be possible only under subsurface drip irrigation. An increased water productivity under drip fertigation was also reported by Dhanalakshmi (1999), Banger and Chaudhari (2004). The increase in water productivity recorded under subsurface drip irrigation system was mainly due to better performance of the crop and increased yield by effective utilization of available water and nutrients that was supplied at regular intervals throughout the crop period to meet the crop demand. The highest water productivity was observed under subsurface drip irrigation in sugarcane. These results are also in accordance with findings of Subramani (2008) and Matheswaran (2008). They reported higher water productivity with water soluble fertilizers under subsurface drip irrigation system.

Surface method of irrigation was prone to more evaporation loss of soil moisture due to more wetting surface upon irrigation apart from reduced cane yield as compared to subsurface drip irrigation. Similar result was also reported by Jadhav *et al.* (1990) and (Lamm *et al.*, 2005).

Table 4.2.1c: Water productivity (t ha cm⁻¹) of plant and ratoon sugarcane at harvest as influenced by duration and levels of fertigation

Treatments	Water productivity	
Fertigation duration (D)		
	Plant cane	Ratoon cane
D₁	1.37	1.27
D₂	1.47	1.35
D₃	1.57	1.44
D₄	1.67	1.52
D₅	1.78	1.60
S.Em ±	0.04	0.04
CD (p=0.05)	0.13	0.12
Fertigation levels (L)		
L₁	1.55	1.41
L₂	1.57	1.43
L₃	1.60	1.46
S.Em ±	0.03	0.03
CD (p=0.05)	NS	NS
Interaction (D×L)		
D₁L₁	1.35	1.25
D₁L₂	1.37	1.26
D₁L₃	1.39	1.29
D₂L₁	1.44	1.32
D₂L₂	1.47	1.35
D₂L₃	1.50	1.37
D₃L₁	1.54	1.40
D₃L₂	1.57	1.43
D₃L₃	1.60	1.47
D₄L₁	1.64	1.50
D₄L₂	1.67	1.51
D₄L₃	1.71	1.54
D₅L₁	1.76	1.58
D₅L₂	1.78	1.60
D₅L₃	1.82	1.62
Control	1.05	1.00
S.Em ±	0.07	0.07
CD (p=0.05)	0.22	0.21

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months
D₂: Fertigation up to 5.0 months
D₃: Fertigation up to 6.5 months
D₄: Fertigation up to 8.0 months
D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF
L₂: 100 % RDF
L₃: 125 % RDF
Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)

4.3 Juice quality parameters of sugarcane (Table 4.3.1a)

4.3.1 Brix, pol, purity and reducing sugar per cent

Quality parameters like brix, pol, purity and reducing sugar per cent of the cane are the deciding factors of the final commercial sugar yield.

Significant difference due to fertigation duration, fertigation levels and their interaction effects under quality parameters of sugarcane were not observed.

4.3.2 Commercial cane sugar (CCS) per cent and sugar yield (Table 4.3.1b)

Significantly higher CCS per cent were recorded under drip fertigation up to 9.5 months (13.48 and 13.26 %) in plant and ratoon cane and on par results were observed under drip fertigation upto 8 months (13.18 and 12.93 %) and 6.5 months (12.83 and 12.59 %) in plant and ratoon cane, respectively.

Whereas, drip fertigation level did not influence the CCS per cent significantly.

The interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher CCS per cent (13.60 and 13.38 %) and on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF (13.47 and 13.29 %) and with 75 per cent RDF (13.37 and 13.12 %) in plant and ratoon cane. Statistically on par results were observed with drip fertigation upto 8.0 and 6.5 months *i.e.*, drip fertigation upto 8.0 with 125 per cent RDF (13.29 and 13.01 %), with 100 per cent RDF (13.17 and 12.93 %) and with 75 per cent RDF (13.09 and 12.86 %) in plant and ratoon cane. Drip fertigation upto 6.5 months with 125 per cent RDF (12.93 and 12.70 %), with 100 per cent RDF (12.84 and 12.60 %) and with 75 per cent RDF (12.71 and 12.46 %) in plant and ratoon cane, respectively. Soil application of 100 per cent RDF with surface irrigation recorded significantly lower CCS per cent of (11.54 and 11.22 %) in plant and ratoon cane.

The higher CCS percentage recorded in subsurface drip fertigation treatment was mainly due to the early formation of millable canes under the sub surface drip systems. In addition to this, the favorable influence was also due to the uniform growth of millable canes with almost equal age under subsurface drip fertigation system (Mahesh, 2009). The uniform maturity of cane at harvest consequently resulted in higher quality characters under drip irrigation compared to surface irrigation. This was in line with the findings of Selvaraj *et al.* (1997). Improvement in juice quality (CCS per cent) of sugarcane with higher level of P and K might be due to increased activity of sucrose synthesizing enzymes in the presence of continuous and adequate moisture under subsurface drip irrigation. Similar findings were also reported by Kumar (2002) and Singh *et al.* (2008).

Table 4.3.1a: Juice quality parameters of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	Brix (%)		Sucrose or Pol (%)		Purity (%)	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	19.85	20.24	18.92	19.04	94.30	95.42
D₂	20.07	20.52	19.24	19.32	94.75	95.55
D₃	20.31	20.90	19.43	19.76	95.13	95.89
D₄	20.59	21.06	19.61	20.12	95.45	96.26
D₅	20.77	21.18	19.82	20.47	95.80	96.71
S.Em ±	0.51	0.37	0.46	0.50	1.24	1.12
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Fertigation levels (L)						
L₁	20.26	20.70	19.34	19.62	94.96	95.87
L₂	20.33	20.78	19.41	19.74	95.06	95.97
L₃	20.37	20.86	19.45	19.86	95.23	96.06
S.Em ±	0.39	0.29	0.36	0.39	0.96	0.86
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	19.80	20.12	18.85	18.96	94.09	95.38
D₁L₂	19.85	20.26	18.92	19.04	94.27	95.41
D₁L₃	19.89	20.35	18.98	19.11	94.53	95.46
D₂L₁	20.00	20.43	19.18	19.17	94.66	95.50
D₂L₂	20.09	20.51	19.25	19.31	94.71	95.55
D₂L₃	20.11	20.63	19.29	19.47	94.87	95.59
D₃L₁	20.25	20.84	19.37	19.58	95.00	95.75
D₃L₂	20.33	20.90	19.43	19.76	95.12	95.90
D₃L₃	20.36	20.96	19.49	19.92	95.27	96.00
D₄L₁	20.50	21.00	19.56	20.00	95.34	96.10
D₄L₂	20.61	21.06	19.61	20.13	95.41	96.29
D₄L₃	20.68	21.12	19.65	20.24	95.58	96.40
D₅L₁	20.73	21.10	19.75	20.36	95.69	96.59
D₅L₂	20.77	21.18	19.83	20.47	95.80	96.70
D₅L₃	20.81	21.26	19.87	20.58	95.91	96.84
Control	18.93	19.63	17.79	17.83	93.29	94.23
S.Em ±	0.88	0.65	0.80	0.87	2.15	1.93
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months
D₂: Fertigation up to 5.0 months
D₃: Fertigation up to 6.5 months
D₄: Fertigation up to 8.0 months
D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF
L₂: 100 % RDF
L₃: 125 % RDF
Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)

Table 4.3.1b: Juice quality parameters of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	Commercial cane sugar (%)		Reducing sugar (%)		Sugar yield (t ha ⁻¹)	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	12.11	12.05	3.30	3.25	23.16	20.25
D₂	12.45	12.33	3.25	3.21	24.27	22.00
D₃	12.83	12.59	3.19	3.14	26.08	24.15
D₄	13.18	12.93	3.10	3.04	28.38	27.29
D₅	13.48	13.26	3.03	2.95	29.97	28.86
S.Em ±	0.29	0.27	0.10	0.11	0.75	1.10
CD (p=0.05)	0.84	0.77	NS	NS	2.17	3.17
Fertigation levels (L)						
L₁	12.71	12.52	3.20	3.15	25.80	23.73
L₂	12.81	12.65	3.18	3.12	26.34	24.57
L₃	12.92	12.73	3.15	3.08	26.98	25.23
S.Em ±	0.22	0.21	0.08	0.08	0.58	0.85
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	12.04	11.94	3.31	3.27	22.77	19.70
D₁L₂	12.11	12.07	3.29	3.25	23.07	20.27
D₁L₃	12.20	12.13	3.28	3.24	23.66	20.79
D₂L₁	12.33	12.24	3.27	3.23	24.01	21.21
D₂L₂	12.45	12.34	3.25	3.21	24.62	21.85
D₂L₃	12.56	12.42	3.24	3.19	24.19	22.95
D₃L₁	12.71	12.46	3.22	3.18	24.94	23.47
D₃L₂	12.84	12.60	3.19	3.14	26.11	24.11
D₃L₃	12.93	12.70	3.17	3.11	27.20	24.87
D₄L₁	13.09	12.86	3.14	3.07	27.73	25.73
D₄L₂	13.17	12.93	3.10	3.05	28.13	27.87
D₄L₃	13.29	13.01	3.07	3.01	29.29	28.29
D₅L₁	13.37	13.12	3.05	3.00	29.56	28.56
D₅L₂	13.47	13.29	3.04	2.97	29.76	28.76
D₅L₃	13.60	13.38	3.00	2.87	30.58	29.25
Control	11.54	11.22	2.82	2.35	15.69	13.75
S.Em ±	0.50	0.46	0.18	0.19	1.30	1.90
CD (p=0.05)	1.45	1.34	NS	NS	3.76	5.48

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Significantly higher sugar yield were recorded under drip fertigation up to 9.5 months (29.97 and 28.86 t ha⁻¹) in plant and ratoon cane and on par results were observed under drip fertigation upto 8 months (28.38 and 27.29 t ha⁻¹) in plant and ratoon cane, respectively.

Whereas, drip fertigation level did not influence the sugar yield significantly.

The interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher sugar yield (30.58 and 29.25t ha⁻¹) and on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF (29.76 and 28.76 t ha⁻¹), with 75 per cent RDF (29.56 and 28.56 t ha⁻¹) in plant and ratoon cane. Statistically on par results were recorded with drip fertigation upto 8.0 months with 125 per cent RDF (29.29 and 28.29 t ha⁻¹), with 100 per cent RDF (28.13 and 27.87 t ha⁻¹) and with 75 per cent RDF (27.73 and 25.73 t ha⁻¹) in plant and ratoon, respectively. Soil application of 100 per cent RDF with surface irrigation recorded significantly lower sugar yield of (15.69 and 13.75 t ha⁻¹) in plant and ratoon cane.

Sugar yield is a function of cane yield and commercial cane sugar percentage. Hence, similar trend as that of cane yield was observed in sugar yield. The increased sugar yield was mainly due to improved juice characters like brix, pol per cent and purity co-efficient and CCS percentage as a result of uniform millable cane production under subsurface drip fertigation treatments. Higher sugar yield under subsurface drip fertigation was also reported by Dhotre *et al.* (2008). Similar result was also reported by Mahesh (2009) and Sathyaraj (2010). The increase in sugar yield was primarily due to the beneficial effect of N and K fertilizers through subsurface drip fertigation in raising the cane yield per unit area and also due to the increased CCS per cent. Similar results were reported by Satisha *et al.* (1996), Singh *et al.* (1997) and Jayaram *et al.* (2010).

Soil application of 100 per cent RDF with surface irrigation recorded lower quality parameters and this might be likely due to lesser availability of nutrients in sugarcane crop. Similar results were also reported by Dagade and Ranadive (1998). They studied water stress in the leaf and its effect on the quality parameters of juice and revealed that stress reduces quality parameters of the cane compared to sugarcane grown under conditions of suitable soil water availability.

4.4 Jaggery quality parameters of sugarcane (Table 4.4.1a and 4.4.1b)

Jaggery quality parameters like juice extraction (%), net rendament value (NR), reducing sugars (%) and jaggery hardness are the deciding factors of the final commercial jaggery yield and recovery.

Jaggery quality parameters like juice extraction per cent, net rendament value, reducing sugars in jaggery and jaggery hardness did not differ significantly due to fertigation duration, fertigation levels and their interaction.

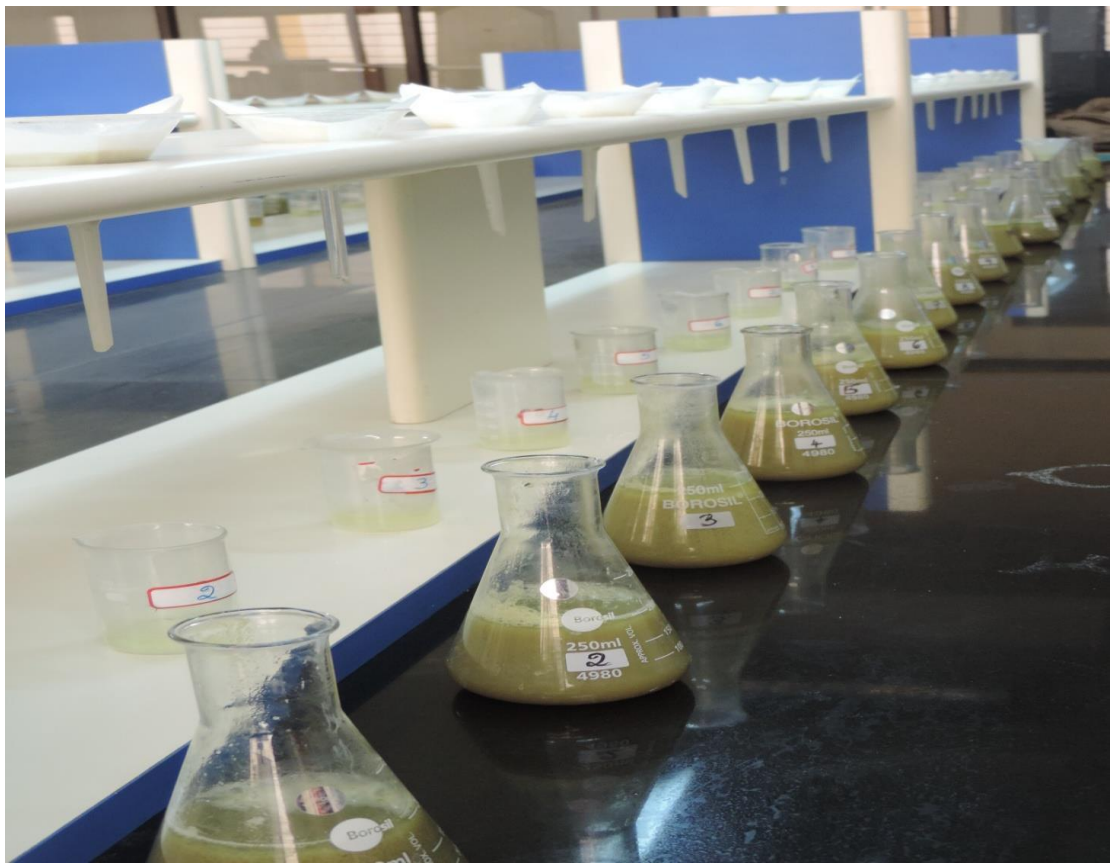


Plate 8: Sugarcane juice analysis

Table 4.4.1a: Jaggery quality parameters of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	Juice extraction (%)		Net rendement value		Jaggery recovery (%)	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	62.59	60.90	61.69	60.91	12.36	11.86
D₂	62.80	61.81	61.88	61.33	12.72	12.31
D₃	63.02	62.64	62.11	61.86	13.04	12.82
D₄	63.68	63.17	62.60	62.37	13.44	13.19
D₅	64.65	63.62	63.52	62.78	13.82	13.45
S.Em ±	1.76	1.16	1.12	0.86	0.34	0.33
CD (p=0.05)	NS	NS	NS	NS	0.97	0.95
Fertigation levels (L)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
L₁	63.18	62.19	62.16	61.69	12.94	12.60
L₂	63.33	62.38	62.38	61.84	13.07	12.72
L₃	63.54	62.72	62.54	62.02	13.22	12.85
S.Em ±	1.36	0.90	0.87	0.67	0.26	0.26
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	62.53	60.61	61.61	60.80	12.20	11.70
D₁L₂	62.59	60.87	61.70	60.91	12.39	11.85
D₁L₃	62.66	61.22	61.77	61.03	12.51	12.03
D₂L₁	62.72	61.70	61.80	61.14	12.60	12.18
D₂L₂	62.80	61.81	61.89	61.26	12.73	12.26
D₂L₃	62.87	61.93	61.96	61.58	12.81	12.48
D₃L₁	62.94	62.27	62.04	61.72	12.90	12.70
D₃L₂	63.01	62.63	62.10	61.87	13.02	12.83
D₃L₃	63.10	63.02	62.19	62.00	13.18	12.95
D₄L₁	63.47	63.08	62.25	62.18	13.30	13.09
D₄L₂	63.66	63.16	62.63	62.36	13.41	13.20
D₄L₃	63.91	63.26	62.93	62.56	13.62	13.27
D₅L₁	64.22	63.31	63.11	62.62	13.70	13.35
D₅L₂	64.60	63.40	63.58	62.78	13.81	13.46
D₅L₃	65.13	64.17	63.87	62.94	13.96	13.55
Control	60.96	59.71	60.90	59.91	11.87	11.10
S.Em ±	3.04	2.02	1.94	1.49	0.58	0.57
CD (p=0.05)	NS	NS	NS	NS	1.68	1.65

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Table 4.4.1b: Jaggery quality parameters of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	Jaggery yield (t ha ⁻¹)		Reducing sugars in jaggery (%)		Jaggery hardness (kg cm ³)	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	23.18	20.11	12.79	12.51	2.17	2.15
D₂	25.20	21.05	12.62	11.96	2.14	2.13
D₃	28.03	23.19	12.45	11.62	2.11	2.10
D₄	30.51	26.03	12.28	11.26	2.08	2.06
D₅	31.92	28.19	11.92	10.86	2.06	2.00
S.Em ±	1.00	1.08	0.30	0.70	0.05	0.06
CD (p=0.05)	2.89	3.11	NS	NS	NS	NS
Fertigation levels (L)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
L₁	27.09	22.94	12.50	11.78	2.12	2.10
L₂	27.79	23.80	12.41	11.64	2.11	2.09
L₃	28.42	24.40	12.33	11.51	2.10	2.07
S.Em ±	0.78	0.83	0.24	0.54	0.04	0.05
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	22.62	19.85	12.84	12.71	2.18	2.16
D₁L₂	23.19	20.10	12.79	12.48	2.17	2.15
D₁L₃	23.74	20.37	12.73	12.35	2.17	2.15
D₂L₁	24.67	20.60	12.68	12.11	2.15	2.14
D₂L₂	25.00	21.04	12.61	11.95	2.14	2.13
D₂L₃	25.94	21.52	12.57	11.83	2.13	2.12
D₃L₁	27.16	21.94	12.50	11.72	2.12	2.11
D₃L₂	27.94	23.62	12.46	11.63	2.10	2.10
D₃L₃	29.00	24.00	12.39	11.51	2.10	2.09
D₄L₁	29.54	24.87	12.34	11.40	2.09	2.08
D₄L₂	30.79	26.00	12.28	11.28	2.08	2.06
D₄L₃	31.21	27.21	12.22	11.11	2.07	2.05
D₅L₁	31.49	27.45	12.11	10.97	2.06	2.05
D₅L₂	32.06	28.22	11.90	10.86	2.06	2.04
D₅L₃	32.21	28.91	11.74	10.74	2.05	2.03
Control	16.70	13.70	11.55	10.37	2.12	2.10
S.Em ±	1.73	1.86	0.53	1.22	0.09	0.08
CD (p=0.05)	5.01	5.38	NS	NS	NS	NS

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)



Plate 9: Jaggery cubes of different treatments

Drip fertigation upto 9.5 months recorded significantly higher jaggery recovery (13.82 and 13.45 %) in plant and ratoon cane. Which was on par with drip fertigation upto 8.0 months (13.44 and 13.19 %) and drip fertigation upto 6.5 months (13.04 and 12.82 %) in plant and ratoon cane.

Statistically there was no significant difference due to drip fertigation level in jaggery recovery.

Significant differences were observed with interaction effect of drip fertigation duration and levels. Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher jaggery recovery (13.96 and 13.55 %) and on par results were recorded with drip fertigation upto 9.5 months with 100 per cent RDF (13.81 and 13.46 %), with 75 per cent RDF (13.70 and 13.35 %) in plant and ratoon cane. However, on par results were observed with drip fertigation upto 8.0 and 6.5 months *i.e.*, drip fertigation upto 8.0 months with 125 per cent RDF (13.62 and 13.27 %), with 100 per cent RDF (13.41 and 13.20 %) and with 75 per cent RDF (13.30 and 13.09 %) in plant and ratoon cane. Drip fertigation upto 6.5 months with 125 per cent RDF (13.18 and 12.95 %), with 100 per cent RDF (13.02 and 12.83 %) and with 75 per cent RDF (12.90 and 12.70 %) in plant and ratoon cane, respectively. Soil application of 100 per cent RDF with surface irrigation recorded significantly lower jaggery recovery of (11.87 and 11.10 %) in plant and ratoon cane.

Drip fertigation upto 9.5 months recorded significantly higher jaggery yield (31.92 and 28.19 t ha⁻¹) in plant and ratoon cane. Which was on par with drip fertigation upto 8.0 months (30.51 and 26.03 t ha⁻¹) in plant and ratoon cane.

Statistically there were no significant difference due to drip fertigation level in jaggery yield.

Significant differences were observed with interaction effect of drip fertigation duration and levels. Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher jaggery yield (32.21 and 28.91 t ha⁻¹) and on par results were recorded with drip fertigation upto 9.5 months with 100 per cent RDF (32.06 and 28.22 t ha⁻¹), with 75 per cent RDF (31.49 and 27.45 t ha⁻¹) in plant and ratoon cane. However, on par results were observed with drip fertigation upto 8.0 months with 125 per cent RDF (31.21 and 27.21 t ha⁻¹), with 100 per cent RDF (30.79 and 26.0 t ha⁻¹) and with 75 per cent RDF (29.54 and 24.87 t ha⁻¹) in plant and ratoon cane, respectively. Soil application of 100 per cent RDF with surface irrigation recorded significantly lower jaggery yield of (16.70 and 13.70 t ha⁻¹) in plant and ratoon cane.

Jaggery quality parameter is mainly dependent on the reducing sugars. TSS, purity and CCS per cent were influenced by higher moisture and nutrients resulted in higher jaggery quality parameters (Jayabal1997). Vasane *et al.* (2008) observed higher juice quality parameters of sugarcane like TSS (total soluble solids), sucrose, purity and CCS per cent and were significantly superior under subsurface drip irrigation resulting in higher jaggery quality parameters compared to other irrigation methods. Higher jaggery hardness was mainly due to lower moisture content under fertigation upto 3.5 months.

Soil application of 100 per cent RDF with surface irrigation recorded lower jaggery quality parameters and this might be due to differences in water and nutrient availability to sugarcane. Similar results were also reported by Aluri (1998) who reported water stress during crop growth stages affect the jaggery quality parameters of the cane compared to sugarcane grown under conditions of suitable soil water availability.

4.5 Available nutrient status of soil after harvest (kg ha^{-1}) (Table 4.5.1a)

The available nutrients in the soil after harvest was significantly influenced by fertigation duration. Higher available nutrients after harvest were observed with drip fertigation upto 9.5 months 365.97 and 336.10 $\text{kg available N ha}^{-1}$, 47.63 and 45.43 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$, 273.91 and 260.86 $\text{kg K}_2\text{O ha}^{-1}$, in plant and ratoon cane. However, on par results were observed with drip fertigation upto 8.0 months 361.81 and 328.32 $\text{kg available N ha}^{-1}$, 46.03 and 43.39 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$, 268.88 and 254.81 $\text{kg K}_2\text{O ha}^{-1}$ in plant and ratoon cane, respectively. Statistically on par results were recorded with drip fertigation upto 6.5 months 355.80 and 322.60 $\text{kg available N ha}^{-1}$, 44.65 and 42.42 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$, 262.93 and 250.56 $\text{kg K}_2\text{O ha}^{-1}$ in plant and ratoon cane, respectively.

Significant difference in post harvest available nutrients were not observed due to drip fertigation levels.

Interaction effect of fertigation duration and fertigation levels on available nutrients in soil after the harvest of crop was found significant. Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher 367.71 and 344.38 $\text{kg available N ha}^{-1}$, 48.45 and 46.76 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 274.83 and 262.29 $\text{kg K}_2\text{O ha}^{-1}$ in plant and ratoon cane. Whereas, on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF 365.41 and 333.08 $\text{kg available N ha}^{-1}$, 47.92 and 45.49 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 274.20 and 261.01 $\text{kg K}_2\text{O ha}^{-1}$, and with 75 per cent RDF 364.78 and 330.83 $\text{kg available N ha}^{-1}$, 46.52 and 44.04 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 272.70 and 259.28 $\text{kg K}_2\text{O ha}^{-1}$, in plant and ratoon cane, respectively. Statistically on par results were observed with drip fertigation upto 8.0 months with 125 per cent RDF 363.03 and 329.79 $\text{kg available N ha}^{-1}$, 46.35 and 43.76 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 270.56 and 257.87 $\text{kg K}_2\text{O ha}^{-1}$, with 100 per cent RDF 362.29 and 328.10 $\text{kg available N ha}^{-1}$, 46.0 and 43.45 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 269.25 and 253.85 $\text{kg K}_2\text{O ha}^{-1}$, with 75 per cent RDF 360.10 and 327.08 $\text{kg available N ha}^{-1}$, 45.75 and 42.96 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 266.82 and 252.70 $\text{kg K}_2\text{O ha}^{-1}$ in plant and ratoon cane, respectively. Similar on par results were recorded with drip fertigation upto 6.5 months with 125 per cent RDF 358.04 and 323.34 $\text{kg available N ha}^{-1}$, 45.22 and 42.79 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 264.60 and 251.19 $\text{kg K}_2\text{O ha}^{-1}$, with 100 per cent RDF 355.52 and 322.48 $\text{kg available N ha}^{-1}$, 44.98 and 42.45 $\text{kg P}_2\text{O}_5\text{ ha}^{-1}$, 263.45 and 250.56 $\text{kg K}_2\text{O ha}^{-1}$, with 75 per cent RDF 353.85 and 321.97 $\text{kg available N ha}^{-1}$, 43.76 and 42.02 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$, 260.74 and 249.93 $\text{kg K}_2\text{O ha}^{-1}$ in plant and ratoon cane, respectively. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower 330.47 and 293.24 $\text{kg available N ha}^{-1}$, 35.71 and 37.15 $\text{kg P}_2\text{O}_5, \text{ha}^{-1}$, 238.59 and 227.26 $\text{kg K}_2\text{O ha}^{-1}$ in plant and ratoon cane, respectively.

Table 4.5.1a: Available nutrients in soil (kg ha⁻¹) after the harvest of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	N		P ₂ O ₅		K ₂ O	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	344.90	309.96	41.05	40.80	250.89	237.91
D₂	350.83	315.96	42.55	41.67	255.65	244.68
D₃	355.80	322.60	44.65	42.42	262.93	250.56
D₄	361.81	328.32	46.03	43.39	268.88	254.81
D₅	365.97	336.10	47.63	45.43	273.91	260.86
S.Em ±	4.56	5.28	1.30	0.98	2.99	3.16
CD (p=0.05)	13.18	15.24	3.77	2.82	8.64	9.11
Fertigation levels (L)						
L₁	354.24	319.78	43.68	42.16	260.66	247.90
L₂	355.76	322.21	44.57	42.80	262.47	249.51
L₃	357.59	325.78	44.90	43.26	264.22	251.88
S.Em ±	3.54	4.09	1.01	0.76	2.32	2.44
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	343.60	305.43	40.81	40.46	249.63	235.93
D₁L₂	344.78	311.90	40.96	40.83	250.81	237.67
D₁L₃	346.32	312.56	41.38	41.10	252.22	240.15
D₂L₁	348.87	313.60	41.56	41.34	253.42	241.66
D₂L₂	350.78	315.47	42.99	41.77	254.64	244.48
D₂L₃	352.86	318.83	43.12	41.90	258.89	247.91
D₃L₁	353.85	321.97	43.76	42.02	260.74	249.93
D₃L₂	355.52	322.48	44.98	42.45	263.45	250.56
D₃L₃	358.04	323.34	45.22	42.79	264.60	251.19
D₄L₁	360.10	327.08	45.75	42.96	266.82	252.70
D₄L₂	362.29	328.10	46.00	43.45	269.25	253.85
D₄L₃	363.03	329.79	46.35	43.76	270.56	257.87
D₅L₁	364.78	330.83	46.52	44.04	272.70	259.28
D₅L₂	365.41	333.08	47.92	45.49	274.20	261.01
D₅L₃	367.71	344.38	48.45	46.76	274.83	262.29
Control	330.47	293.24	35.71	37.15	238.59	227.26
S.Em ±	7.90	9.14	2.26	1.69	5.18	5.47
CD (p=0.05)	22.83	26.39	6.53	4.88	14.96	15.79

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Generally, subsurface drip fertigation recorded higher availability of nutrients. The increased availability of nutrients might be due to split application of fertilizers up to 210 DAP under subsurface drip fertigation that resulted in reduction in loss of nutrients thereby making them available continuously to the crop. Similar findings of higher available NPK with drip fertigation of nutrients was also reported by Selvakumar (2006). The increased level of N and K application to sugarcane through subsurface drip fertigation have increased the availability of nutrients in soil. Similar findings were also reported by Shukla *et al.* (2007) and Aneg Singh *et al.* (2007).

Soil application of 100 per cent RDF with surface irrigation recorded lower available nutrients. This was mainly due to the fact that soil applied nutrients was subjected to various losses and found to leach out to deeper layers. Similar findings were also observed by Shobana (2002).

4.5.1 Nutrient uptake (kg ha⁻¹) (Table 4.5.1b)

Drip fertigation upto 9.5 months recorded significantly higher N uptake (342.16 and 330.16 kg ha⁻¹), P uptake (45.84 and 42.95 kg ha⁻¹) and K uptake (261.67 and 234.0 kg ha⁻¹) in plant and ratoon cane. Whereas, drip fertigation upto 8.0 months recorded on par results of N uptake (335.52 and 322.19 kg ha⁻¹), P uptake (43.64 and 41.94 kg ha⁻¹) and K uptake (253.59 and 225.12 kg ha⁻¹) in plant and ratoon cane. Statistically on par results were observed with drip fertigation upto 6.5 months of N uptake (327.41 and 314.96 kg ha⁻¹), P uptake (41.81 and 40.94 kg ha⁻¹) and K uptake (246.59 and 217.03 kg ha⁻¹) in plant and ratoon cane, respectively.

Drip fertigation level did not influence the nutrient uptake of plant and ratoon cane significantly.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher N uptake (345.41 and 334.41 kg ha⁻¹), P uptake (46.22 and 43.22 kg ha⁻¹) and K uptake (264.96 and 237.29 kg ha⁻¹) in plant and ratoon cane. Statically on par results were observed with drip fertigation upto 9.5 months with 100 per cent RDF N uptake (341.66 and 329.99 kg ha⁻¹), P uptake (45.98 and 42.98 kg ha⁻¹) and K uptake (261.49 and 234.15 kg ha⁻¹), with 75 per cent RDF N uptake (339.41 and 326.08 kg ha⁻¹), P uptake (45.31 and 42.64 kg ha⁻¹) and K uptake (258.56 and 230.56 kg ha⁻¹) in plant and ratoon cane. Statistically on par results were recorded with drip fertigation upto 8.0 months and 6.5 months i.e., drip fertigation upto 8.0 months with 125 per cent RDF N uptake (338.25 and 324.92 kg ha⁻¹), P uptake (44.82 and 42.29 kg ha⁻¹) and K uptake (256.70 and 227.70 kg ha⁻¹), with 100 per cent RDF N uptake (335.56 and 321.89 kg ha⁻¹), P uptake (43.60 and 41.94 kg ha⁻¹) and K uptake (253.37 and 225.63 kg ha⁻¹), with 75 per cent RDF N uptake (332.75 and 319.75 kg ha⁻¹), P uptake (42.50 and 41.60 kg ha⁻¹) and K uptake (250.69 and 222.03 kg ha⁻¹) in plant and ratoon cane, respectively. Drip fertigation upto 6.5 months with 125 per cent RDF recorded on par results N uptake (329.19 and 316.19 kg ha⁻¹), P uptake (42.11 and 41.23 kg ha⁻¹) and K uptake (248.05 and 219.05 kg ha⁻¹), with 100 per cent RDF N uptake (327.52 and 315.52 kg ha⁻¹), P uptake (41.83 and 40.88 kg ha⁻¹) and K uptake (246.82 and 217.15 kg ha⁻¹), with 75 per cent RDF N uptake (325.50 and 313.17 kg ha⁻¹), P uptake (41.49 and 40.71 kg ha⁻¹) and K uptake (244.89 and 214.89 kg ha⁻¹) in plant and ratoon cane, respectively.

However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower N uptake (297.24 and 283.95 kg ha⁻¹), P uptake (32.60 and 29.84 kg ha⁻¹) and K uptake (217.78 and 193.35 kg ha⁻¹) in plant and ratoon cane, respectively.

Higher NPK uptake was the result of significantly higher dry matter production at all the growth stages of sugarcane. Secondly, the increase in uptake might be due to better availability of nutrients in the effective root zone as a result of frequent application of nutrients coupled with better root activity. Further, it was also due to reduced loss of nutrients primarily because of less leaching in fertigation compared to surface irrigation with soil application of RDF. The increased nutrient uptake under subsurface drip fertigation was mainly due to continuous availability of higher soil moisture content that helped in solubilising the plant nutrients near the root zone, which favoured easy absorption of the plant nutrients by the crop. Further, the production of more fibrous roots near the emitter point might also increase the root contact area with the soil, which ultimately helped to remove more nutrients into the plant system. This resulted in increased production of dry matter and uptake under subsurface drip fertigation system.

Chitra (1992) reported that sugarcane absorbed N from soil solution mostly in the form of NH₄-N and hence applied fertilizer was transformed into this assimilable and metabolisable form. The increase in nutrient uptake was also due to the split application of nutrients from 15 days after ratooning to 210 days after ratooning in 33 equal splits. This in turn resulted in reduction in loss of nutrients and also making them available continuously to the crop. This result was in accordance with the finding of Kittad *et al.* (1995). Similar observations of increased nutrient uptake as a result of fertigation have been reported by Hebbar *et al.* (2004). Gouthaman (1997) observed that when nutrients was applied in splits to root zone through subsurface drip fertigation system, roots readily absorbed the nutrients in wetted soil profile. Similar findings of increased NPK uptake under drip irrigation was also reported by Dhanalakshmi (1999), Mahendran *et al.* (2005) and Mahesh (2009) in sugarcane.

In the conventional method of fertilizer application with surface irrigation, nutrients was applied to the top soil layer. This layer was subjected to alternate drying and wetting cycles due to longer irrigation intervals. Low soil water content as well as higher fixation with soil colloids had reduced the availability of applied nutrients that led to lower uptake of nutrients by the sugarcane crop. Similar absorption pattern with varying irrigation methods was narrated by Escobar (1995).

4.5.2 Nutrient use efficiency (t kg⁻¹) (Table 4.5.1c)

Nutrient use efficiency was significantly influenced by fertigation duration. Significantly higher N use efficiency of (1.0 and 0.90 t kg⁻¹), P (2.50 and 2.24 t kg⁻¹) and K (2.0 and 1.79 t kg⁻¹) were recorded with drip fertigation upto 9.5 months in plant and ratoon cane. However, on par results were observed with drip fertigation upto 8.0 months with use efficiency of N (0.94 and 0.85 t kg⁻¹), P (2.34 and 2.12 t kg⁻¹) and K (1.87 and 1.70 t kg⁻¹) in plant and ratoon cane, respectively.

The nutrient use efficiency was not influenced by drip fertigation levels.

Table 4.5.1b: Nutrient uptake (kg ha⁻¹) of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	N		P		K	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	314.67	303.56	39.53	37.13	235.04	204.04
D₂	320.90	308.90	40.97	39.81	240.36	210.03
D₃	327.41	314.96	41.81	40.94	246.59	217.03
D₄	335.52	322.19	43.64	41.94	253.59	225.12
D₅	342.16	330.16	45.84	42.95	261.67	234.00
S.Em ±	5.93	6.01	1.29	1.10	4.23	4.46
CD (p=0.05)	17.12	17.35	3.73	3.19	12.21	12.89
Fertigation levels (L)						
L₁	325.78	313.64	41.60	39.85	245.33	215.47
L₂	328.14	315.81	42.45	40.59	247.19	218.17
L₃	330.47	318.40	43.02	41.23	249.83	220.49
S.Em ±	4.59	4.65	1.00	0.85	3.28	3.46
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	312.97	301.64	37.85	35.23	233.93	202.27
D₁L₂	314.59	303.25	39.94	37.24	234.37	204.04
D₁L₃	316.45	305.79	40.78	38.91	236.82	205.82
D₂L₁	318.25	307.58	40.83	39.06	238.59	207.59
D₂L₂	321.40	308.40	40.90	39.90	239.89	209.89
D₂L₃	323.05	310.71	41.18	40.48	242.60	212.60
D₃L₁	325.50	313.17	41.49	40.71	244.89	214.89
D₃L₂	327.52	315.52	41.83	40.88	246.82	217.15
D₃L₃	329.19	316.19	42.11	41.23	248.05	219.05
D₄L₁	332.75	319.75	42.50	41.60	250.69	222.03
D₄L₂	335.56	321.89	43.60	41.94	253.37	225.63
D₄L₃	338.25	324.92	44.82	42.29	256.70	227.70
D₅L₁	339.41	326.08	45.31	42.64	258.56	230.56
D₅L₂	341.66	329.99	45.98	42.98	261.49	234.15
D₅L₃	345.41	334.41	46.22	43.22	264.96	237.29
Control	297.24	283.95	32.60	29.84	217.78	193.35
S.Em ±	10.26	10.41	2.24	1.91	7.32	7.73
CD (p=0.05)	29.65	30.05	6.47	5.52	21.15	22.32

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

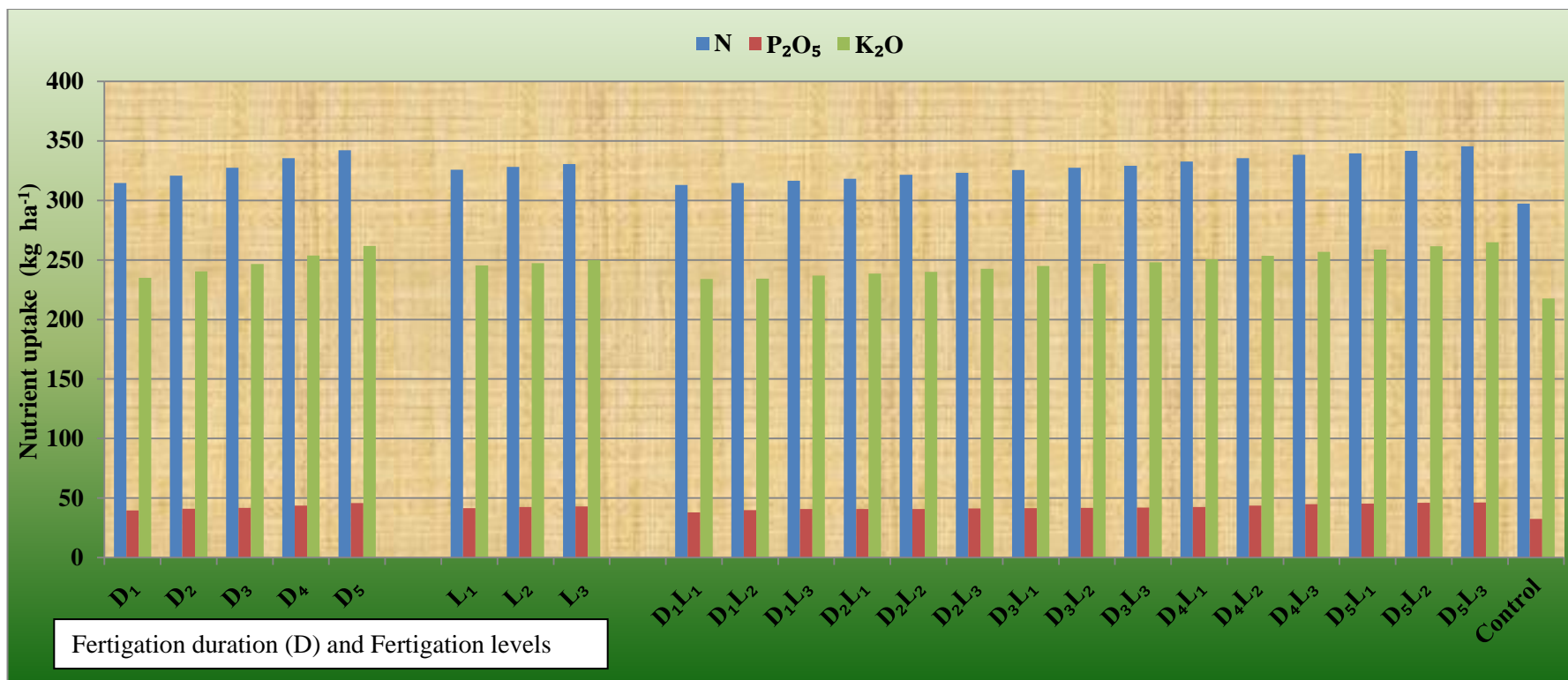
Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)



Note:

Factor A:

Fertigation duration

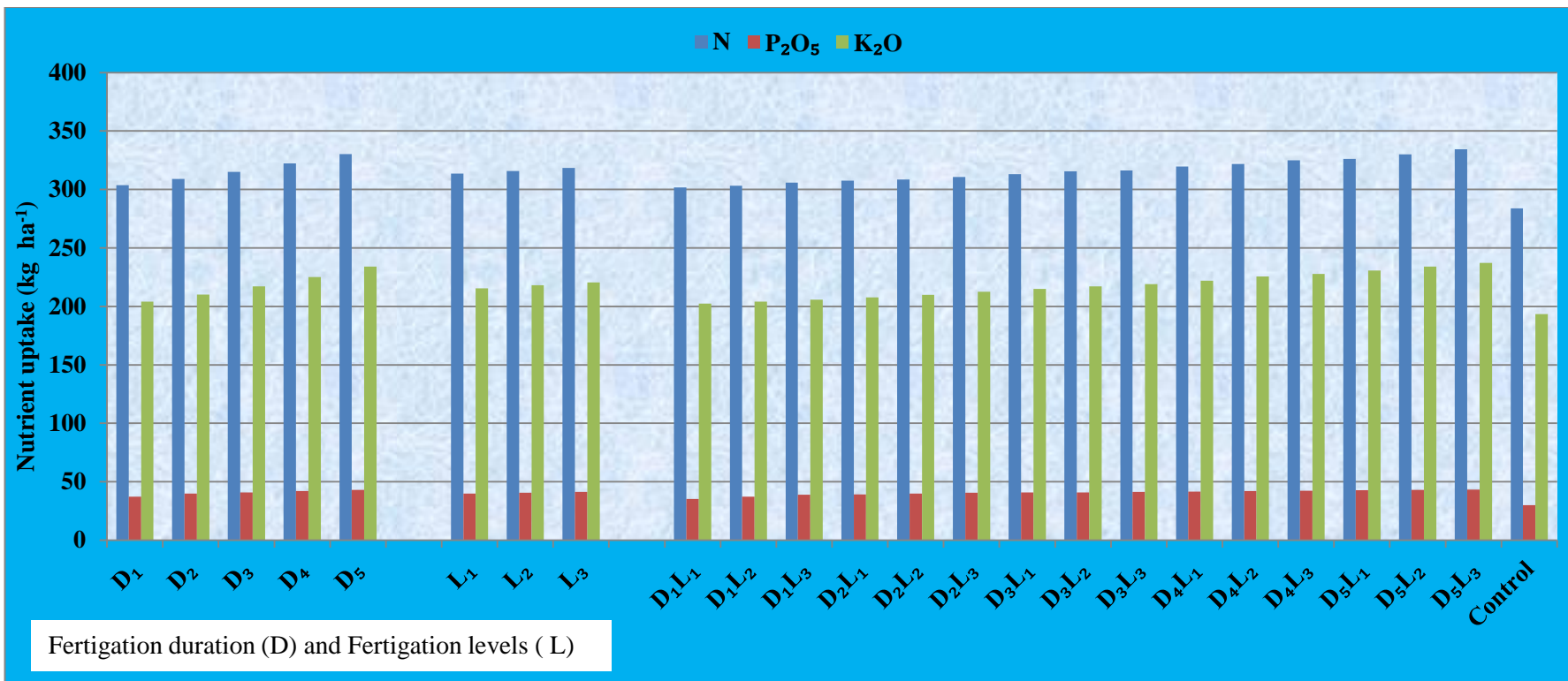
D₁: Fertigation up to 3.5 months
 D₂: Fertigation up to 5.0 months
 D₃: Fertigation up to 6.5 months
 D₄: Fertigation up to 8.0 months
 D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100% RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.6: Nutrient uptake (kg ha⁻¹) of plant cane as influenced by fertigation duration and levels



Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months
 D₂: Fertigation up to 5.0 months
 D₃: Fertigation up to 6.5 months
 D₄: Fertigation up to 8.0 months
 D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100 % RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.7: Nutrient uptake (kg ha⁻¹) of ratoon cane as influenced by fertigation duration and levels

Table 4.5.1c: Nutrient use efficiency (t kg⁻¹) of plant and ratoon sugarcane at harvest as influenced by duration and levels of fertigation

Treatments	N		P		K	
Fertigation duration (D)						
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	0.77	0.71	1.92	1.77	1.54	1.42
D₂	0.82	0.75	2.06	1.89	1.65	1.51
D₃	0.88	0.80	2.20	2.01	1.76	1.61
D₄	0.94	0.85	2.34	2.12	1.87	1.70
D₅	1.00	0.90	2.50	2.24	2.00	1.79
S.Em ±	0.02	0.02	0.06	0.06	0.05	0.05
CD (p=0.05)	0.07	0.07	0.18	0.17	0.14	0.14
Fertigation levels (L)						
L₁	0.87	0.79	2.17	1.97	1.73	1.58
L₂	0.88	0.80	2.20	2.00	1.76	1.60
L₃	0.90	0.82	2.25	2.04	1.80	1.63
S.Em ±	0.02	0.02	0.05	0.05	0.04	0.04
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	0.76	0.70	1.89	1.75	1.51	1.40
D₁L₂	0.77	0.71	1.92	1.77	1.54	1.41
D₁L₃	0.78	0.72	1.95	1.81	1.56	1.44
D₂L₁	0.81	0.74	2.01	1.85	1.61	1.48
D₂L₂	0.82	0.75	2.06	1.89	1.65	1.51
D₂L₃	0.84	0.77	2.10	1.92	1.68	1.54
D₃L₁	0.87	0.79	2.16	1.96	1.73	1.57
D₃L₂	0.88	0.80	2.19	2.00	1.75	1.60
D₃L₃	0.90	0.83	2.24	2.06	1.79	1.65
D₄L₁	0.92	0.84	2.30	2.10	1.84	1.68
D₄L₂	0.93	0.85	2.34	2.12	1.87	1.69
D₄L₃	0.96	0.86	2.39	2.15	1.91	1.72
D₅L₁	0.98	0.88	2.46	2.21	1.97	1.77
D₅L₂	1.00	0.90	2.49	2.25	1.99	1.80
D₅L₃	1.02	0.91	2.55	2.27	2.04	1.82
Control	0.59	0.56	1.47	1.40	1.17	1.12
S.Em ±	0.04	0.04	0.10	0.10	0.08	0.08
CD (p=0.05)	0.12	0.12	0.30	0.30	0.24	0.24

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

However, the interaction effect of fertigation duration and fertigation levels on nutrient use efficiency was found to be significant. Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher N (1.02 and 0.91 t kg⁻¹), P (2.55 and 2.27 t kg⁻¹) and K (2.04 and 1.82 t kg⁻¹) use efficiency in plant and ratoon cane, respectively. However, on par results were observed with drip fertigation upto 9.5 months with 100per cent RDFN (1.0 and 0.90 t kg⁻¹), P (2.49 and 2.25 t kg⁻¹) and K (1.99 and 1.80 t kg⁻¹) use efficiency and with 75 per cent RDFN (0.98 and 0.88 t kg⁻¹), P (2.46 and 2.21 t kg⁻¹) and K (1.97 and 1.77 t kg⁻¹) use efficiency in plant and ratoon cane, respectively. Statistically on par results were recorded with drip fertigation upto 8.0 months with 125 per cent RDF N (0.96 and 0.86 t kg⁻¹), P (2.39 and 2.15 t kg⁻¹) and K (1.91 and 1.72 t kg⁻¹) use efficiency, with 100 per cent RDFN (0.93 and 0.85 t kg⁻¹), P (2.34 and 2.12 t kg⁻¹) and K (1.87 and 1.69 t kg⁻¹) use efficiency and with 75 per cent RDF N (0.92 and 0.84 t kg⁻¹), P (2.30 and 2.10 t kg⁻¹) and K (1.84 and 1.68 t kg⁻¹) use efficiency in plant and ratoon cane, respectively. However, soil application of 100 per cent RDF with surface irrigation recorded significantly lower N (0.59 and 0.56 t kg⁻¹ respectively), P (1.47 and 1.40 t kg⁻¹, respectively) and K (1.17 and 1.12 t kg⁻¹, respectively) use efficiency in plant and ratoon cane, respectively.

Efficient use of fertilizers is necessary for optimum growth and yield of sugarcane. Hence, knowledge about the availability of nutrients in the soil is very essential. A clear understating of specific requirement of the crop during various stages of crop growth will substantially reduce the possible wastage of applied nutrients and improve the potentiality of the plant and the nutrient use efficiency.

This could be attributed to regular application nutrients combined with water application to the active root zone of the crop and minimum leaching of nutrients away from the root zone. This was in harmony with the findings of Veeraputhiran (2000), Aujla *et al.* (2005) and Subramani (2008). They had reported higher nutrient use efficiency under drip fertigation compared to soil application of fertilizer. The horizontal and vertical movement of N, P and K was greatly enhanced under drip fertigation system and the available nutrient concentration was higher resulted in higher nutrient use efficiency (Matheswaran, 2008).

Plant nutrient availability in the soil is very important factor for exploiting higher cane production. The applied nutrients at any stage of the cane should properly reflect in terms of available nutrient in the soil, so that cane could absorb these nutrients without hindrance. Leaching of nutrients, volatilization of the fertilizers and fixation of nutrients in the soil are some of the factors that affect the availability of soil applied nutrients. Similar results was also reported by (Debashis Chakraborty *et al.*, 1999).

4.6 Soil microbial population

Soil microbial population was not influenced significantly by fertigation duration, levels and their interaction.

However, numerically higher bacteria (38.28 and 46.72 No.X10⁶ CFU g⁻¹), fungi (9.06 and 11.19 No.X10⁴ CFU g⁻¹) and actinomycetes (5.23 and 7.44 No.X10³

CFU g⁻¹) populations were recorded in plant and ratoon cane with drip fertigation upto 3.5 months.

Use of chemical fertilizer have resulted in lower microbial population besides affecting the microbial population (Rakkiyappan *et al.*, 2001). Sreelatha *et al.* (2014) revealed that application of chemical fertilizers had positive effect on soil physical, biological and nutrient status.

4.7 Economics (Table 4.7 and appendix)

The economics of sugarcane cultivation differed due to different drip fertigation duration and fertilizer levels since it was a result of price and yield of marketable produce, cost of cultivation which varied in relation to different inputs used, and in turn net returns and B:C ratio.

Drip fertigation upto 9.5 months recorded higher gross return, net return and B:C ratio in plant and ratoon cane (₹. 549687 and 493233 ha⁻¹), (₹. 441121 and 410268 ha⁻¹) and (5.06 and 5.95) and was followed by drip fertigation upto 8.0 months with gross return, net return and B:C ratio of (₹515384 and 467060 ha⁻¹), (₹ 406818 and 384094 ha⁻¹) and (4.75 and 5.63) in plant and ratoon cane, respectively.

Drip fertigation level at 125 per cent RDF recorded higher gross return and net return in plant and ratoon cane (₹. 494187 and 449466 ha⁻¹) and (₹. 382755 and 363634 ha⁻¹). Whereas, lower gross return and net return (₹. 483942 and 440876 ha⁻¹) and (₹. 375377 and 357910 ha⁻¹) were recorded with 100 per cent RDF and with 75 per cent RDF (₹. 476313 and 434285 ha⁻¹) and (₹. 370613 and 354185 ha⁻¹). Higher B:C ratio was observed with 75 per cent RDF (4.51 and 5.42, respectively) and numerically lower B:C ratio was observed with 100 per cent RDF (4.46 and 5.31) and 125 per cent RDF (4.43 and 5.24) in plant and ratoon cane, respectively.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF recorded higher gross return and net return (₹. 560325 and 499538 ha⁻¹) and (₹. 448893 and 413706 ha⁻¹) in plant and ratoon cane. Similar trend were recorded with drip fertigation upto 9.5 months with 100 and 75 per cent RDF. However, B:C ratio was higher under drip fertigation upto 9.5 months with 75 per cent RDF (5.12 and 6.07). However, surface irrigation with soil application of 100 per cent RDF recorded lower gross return, net return and B:C ratio in plant and ratoon cane.

Drip fertigation through subsurface drip irrigation system is an innovative technology for maximizing the yield. Though the cost of drip irrigation unit was high, considering longer life period of drip irrigation system, the benefit accrued out of drip irrigation will be for longer period. However, cost was compensated by higher net return obtained by higher yield and quality produces. The higher gross return, net return and B:C ratio were mainly due to higher cane and sugar yield as reported by (Jayabal 1997), (Selvakumar, 2006), (Sharmasarkar *et al.*, 2001) and (Veeraputhiran, 2000). Soil application of 100 per cent RDF with surface irrigation recorded lower gross return, net return and B:C ratio and was mainly due lower cane and sugar yield. This was in conformity with the findings of (Subramani, 2008).

Table 4.6: Soil microbial population of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	Bacteria (No.×10 ⁶ CFU g ⁻¹)		Fungi (No.×10 ⁴ CFU g ⁻¹)		Actinomycetes (No.×10 ³ CFU g ⁻¹)	
Fertigation duration (D)						
	Plant crop	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	38.28	46.72	9.06	11.19	5.23	7.44
D₂	38.06	46.56	8.97	10.89	5.13	7.28
D₃	37.89	46.36	8.86	10.52	4.99	7.16
D₄	37.70	46.19	8.72	10.29	4.82	7.02
D₅	37.53	45.94	8.56	10.06	4.68	6.97
S.Em ±	0.70	0.61	0.43	0.44	0.59	0.40
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Fertigation levels (L)						
L₁	37.96	46.42	8.87	10.64	5.01	7.20
L₂	37.89	46.35	8.84	10.59	4.97	7.23
L₃	37.83	46.29	8.79	10.54	4.93	7.10
S.Em ±	0.54	0.47	0.33	0.34	0.45	0.31
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction (D×L)						
D₁L₁	38.38	46.76	9.10	11.01	5.26	7.49
D₁L₂	38.27	46.72	9.07	11.31	5.22	7.44
D₁L₃	38.19	46.67	9.03	11.25	5.21	7.38
D₂L₁	38.13	46.65	8.99	11.19	5.17	7.33
D₂L₂	38.04	46.55	8.97	10.78	5.13	7.28
D₂L₃	38.00	46.50	8.94	10.71	5.09	7.24
D₃L₁	37.93	46.42	8.90	10.66	5.05	7.20
D₃L₂	37.90	46.36	8.86	10.29	4.99	7.16
D₃L₃	37.84	46.30	8.81	10.59	4.92	7.13
D₄L₁	37.77	46.26	8.76	10.22	4.87	7.07
D₄L₂	37.70	46.20	8.73	10.51	4.81	7.03
D₄L₃	37.63	46.12	8.65	10.13	4.79	6.96
D₅L₁	37.57	46.03	8.60	10.10	4.73	6.91
D₅L₂	37.54	45.94	8.56	10.06	4.67	7.23
D₅L₃	37.50	45.86	8.51	10.01	4.65	6.78
Control	41.52	49.26	11.74	13.59	8.77	9.62
S.Em ±	1.20	1.06	0.74	0.76	1.01	0.70
CD (p=0.05)	NS	NS	NS	NS	NS	NS

Note:

Factor A:

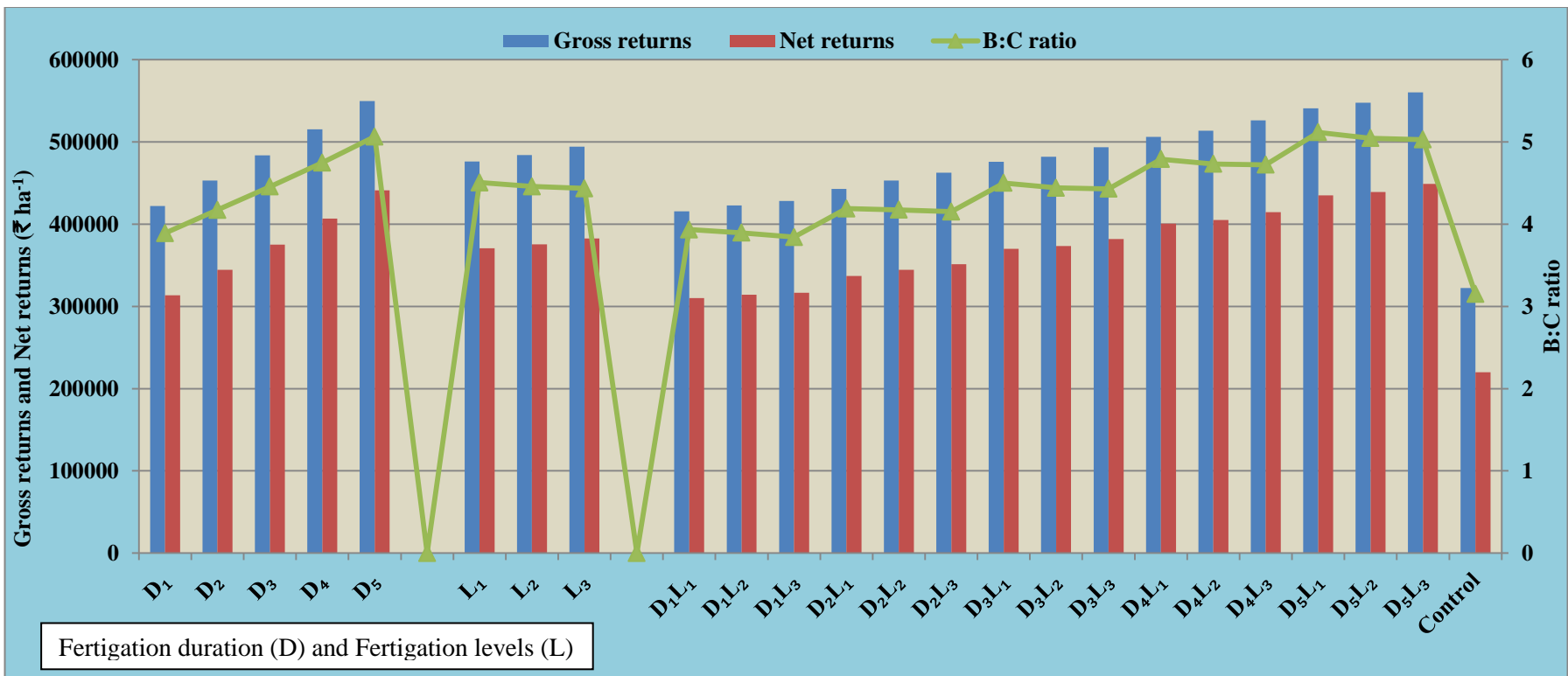
Fertigation duration

D₁: Fertigation up to 3.5 months
D₂: Fertigation up to 5.0 months
D₃: Fertigation up to 6.5 months
D₄: Fertigation up to 8.0 months
D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF
L₂: 100 % RDF
L₃: 125 % RDF
Control: Soil application of 100 % RDF with surface irrigation.
(RDF-250:100:125 NPK kg ha⁻¹)



Note:

Factor A:

Fertigation duration

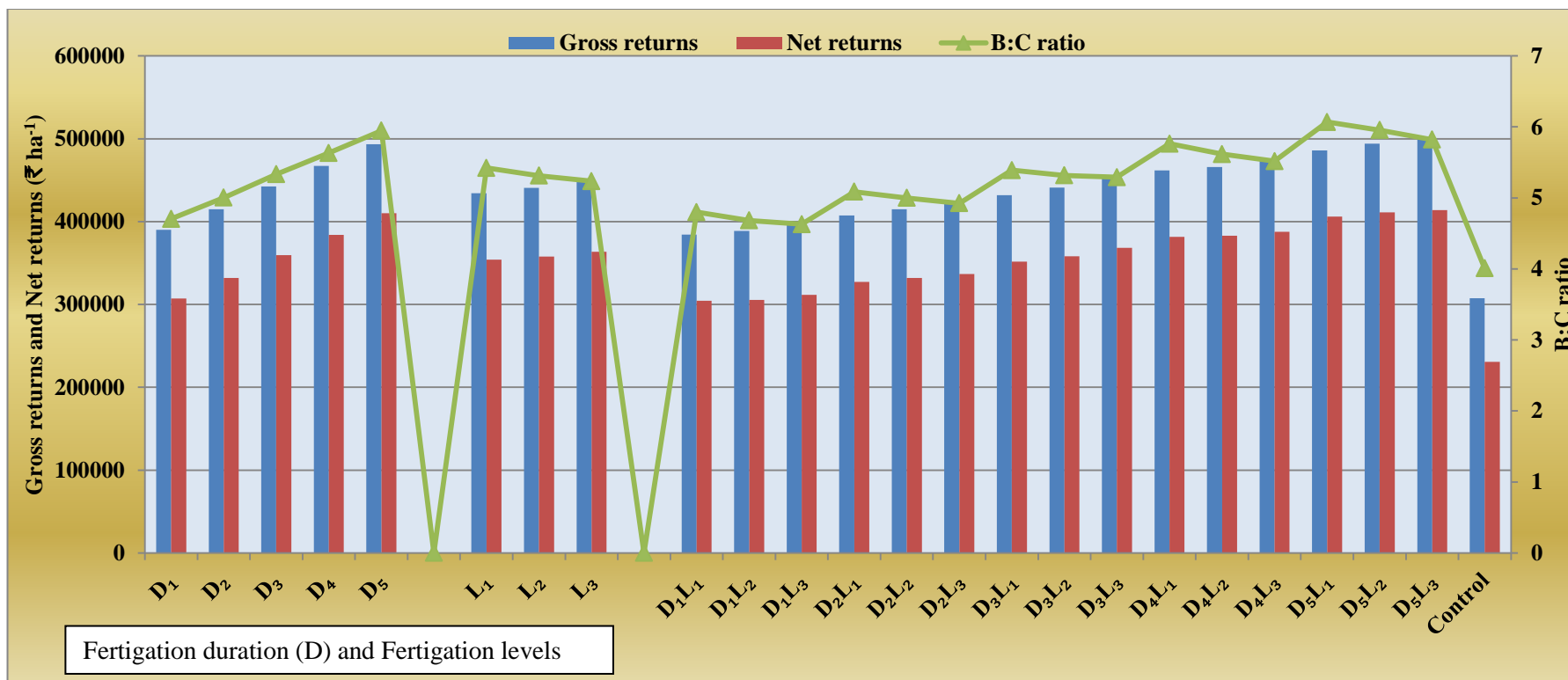
D₁: Fertigation up to 3.5 months
 D₂: Fertigation up to 5.0 months
 D₃: Fertigation up to 6.5 months
 D₄: Fertigation up to 8.0 months
 D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100% RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.8: Gross returns, net returns and B:C ratio of plant cane as influenced by fertigation duration and levels



Note:

Factor A:

Fertilization duration

D₁: Fertilization up to 3.5 months
 D₂: Fertilization up to 5.0 months
 D₃: Fertilization up to 6.5 months
 D₄: Fertilization up to 8.0 months
 D₅: Fertilization up to 9.5 months

Factor B:

Fertilization levels

L₁: 75% RDF
 L₂: 100% RDF
 L₃: 125% RDF
 Control: Soil application of 100% RDF with surface irrigation.
 (RDF-250:100:125 NPK kg ha⁻¹)

Fig. 4.9: Gross returns, net returns and B:C ratio of ratoon cane as influenced by fertilization duration and levels

Table 4.7: Economics of plant and ratoon sugarcane as influenced by duration and levels of fertigation

Treatments	Cost of cultivation (₹ ha ⁻¹)		Gross return (₹ ha ⁻¹)		Net return (₹ ha ⁻¹)		B:C ratio	
Fertigation duration (D)								
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
D₁	108565	82965	42224	390099	313680	307133	3.89	4.70
D₂	108565	82965	452918	414967	344353	332001	4.17	5.00
D₃	108565	82965	483836	442352	375270	359387	4.46	5.33
D₄	108565	82965	515384	467060	406818	384094	4.75	5.63
D₅	108565	82965	549687	493233	441121	410268	5.06	5.95
S.Em ±	NA		NA		NA		NA	
CD (p=0.05)	NA		NA		NA		NA	
Fertigation levels (L)								
	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane	Plant cane	Ratoon cane
L₁	105699	80099	476313	434285	370613	354185	4.51	5.42
L₂	108565	82965	483942	440876	375377	357910	4.46	5.31
L₃	111431	85831	494187	449466	382755	363634	4.43	5.24
S.Em ±	NA		NA		NA		NA	
CD (p=0.05)	NA		NA		NA		NA	
Interaction (D×L)								
D₁L₁	105699	80099	415807	384457	310108	304357	3.93	4.80
D₁L₂	108565	82965	422818	388553	314252	305588	3.89	4.68
D₁L₃	111431	85831	428112	397287	316680	311455	3.84	4.63
D₂L₁	105699	80099	442779	407443	337080	327344	4.19	5.09
D₂L₂	108565	82965	453207	414772	344641	331806	4.17	5.00
D₂L₃	111431	85831	462770	422686	351338	336854	4.15	4.92
D₃L₁	105699	80099	475830	431805	370131	351706	4.50	5.39
D₃L₂	108565	82965	482137	441049	373571	358083	4.44	5.32
D₃L₃	111431	85831	493540	454203	382108	368371	4.43	5.29
D₄L₁	105699	80099	506264	461654	400564	381554	4.79	5.76
D₄L₂	108565	82965	513700	465908	405134	382943	4.73	5.62
D₄L₃	111431	85831	526188	473618	414756	387786	4.72	5.52
D₅L₁	105699	80099	540884	486064	435185	405965	5.12	6.07
D₅L₂	108565	82965	547851	494097	439285	411132	5.05	5.96
D₅L₃	111431	85831	560325	499538	448893	413706	5.03	5.82
Control	102300	76700	322351	307420	220051	230720	3.15	4.01
S.Em ±	NA		NA		NA		NA	
CD (P=0.05)	NA		NA		NA		NA	

Note:

Factor A:

Fertigation duration

D₁: Fertigation up to 3.5 months

D₂: Fertigation up to 5.0 months

D₃: Fertigation up to 6.5 months

D₄: Fertigation up to 8.0 months

D₅: Fertigation up to 9.5 months

Factor B:

Fertigation levels

L₁: 75 % RDF

L₂: 100 % RDF

L₃: 125 % RDF

Control: Soil application of 100 % RDF with surface irrigation. (RDF-250:100:125 NPK kg ha⁻¹)

Thus, from the foregoing results and discussion, in addition to higher yield and income, higher quantity of irrigation water saving coupled with higher water and nutrient use efficiencies indicate the practical feasibility of subsurface drip fertigation in sugarcane production. Subsurface drip fertigation may also provide opportunity to bring additional area under cultivation to meet the domestic and export demands of sugar.

Practical utility of the investigation

- ❖ Application of N and K fertilizer through subsurface drip fertigation upto 8 to 9.5 months was found beneficial for enhancing cane yield by 59 and 70 per cent in plant cane and 52 to 61 per cent in ratoon cane.
- ❖ Application of 75 per cent recommended dose of fertilizer through subsurface drip fertigation was found to record higher yield over conventional method of sugarcane cultivation in both plant and ratoon cane.
- ❖ Fertigation scheduling upto 8 to 9.5 months duration with recommended dose of fertilizer of 75 per cent through subsurface drip fertigation known to record higher yield besides recording better juice and jaggery quality parameters.
- ❖ Drip fertigation upto 9.5 months with 75 per cent recommended dose of fertilizer recorded higher B:C ratio both in plant and ratoon cane over surface irrigation with 100 per cent recommended dose of fertilizer.

Future line of work

- ❖ The fertigation duration and frequency of fertigation needs to be studied in order to exploit the full potentiality of the cane production.
- ❖ Nutrient dynamics in relation to crop uptake and losses through percolation and volatilization needs to be studied for improving nutrient use efficiency.

V SUMMARY

Sugarcane is an important commercial crop with duration of twelve to sixteen months, where in conventional application of recommended dose of fertilizer within three and a half to four months and surface flood irrigation lead to considerable loss of water and leaching of applied mobile nutrients resulting in low productivity. In this context an experiment on “Standardization of fertigation scheduling in sugarcane through subsurface drip irrigation” was carried out in plant and ratoon cane, with the objectives to study the effect of fertigation duration and levels on growth and yield, quality of sugarcane juice and jaggery, nutrient use efficiency, water productivity and economics of sugarcane.

The experiment was laid out in Factorial randomized complete block design (FRCBD) with three replications during 2014-15 and 2015-16 at ZARS, VC farm Mandya, GKVK, Bengaluru. During the course of investigation, growth parameters were recorded at different growth stages and yield parameters, juice and jaggery quality parameters were assessed at harvest besides, the initial and final nutrient status and economics of sugarcane cultivation. The salient findings of the investigation are summarized as follows.

Growth parameters of plant and ratoon cane differed significantly, and recorded higher plant height (330.6 and 296.2 cm), number of tillers m^{-1} (34.66 and 43.33), total dry matter production (652.57 and 466.91 g plant⁻¹) at harvest and SPAD reading at 240 DAP (34.67 and 37.72) with drip fertigation upto 9.5 months and was on par with drip fertigation upto 8.0 months.

Fertigation levels did not influence the plant height (316.3 and 287.5 cm), number of tillers m^{-1} (34.14 and 42.63), total dry matter production (621.20 and 437.92 g plant⁻¹) and SPAD readings (31.41 and 34.31) irrespective of growth stages in plant and ratoon cane, respectively. However drip fertigation level at 100 and 75 per cent RDF recorded lower growth and growth parameters.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher growth parameters like plant height (332.52 and 299.52 cm), number of tillers m^{-1} in (34.97 and 43.98), total dry matter production (658.70 and 473.37 g plant⁻¹) at harvest and SPAD reading at 240 DAP (34.92 and 37.82), respectively in plant and ratoon cane and on par results were observed with drip fertigation upto 9.5 months with 100 and 75 per cent RDF. However, normal method of cane cultivation under surface irrigation recorded significantly lower growth parameters.

Yield and yield parameters of plant and ratoon cane differed significantly with respect to number of millable canes m^{-1} (26.45 and 27.47), cane length (2.35 and 2.26 m), single cane weight (1.70 and 1.50 kg), cane yield (250 and 224 t ha⁻¹) and water productivity (1.78 and 1.60 t ha cm⁻¹). However, it was on par with drip fertigation upto 8.0 months.

Drip fertigation with 125 per cent RDF recorded significantly higher number of millable canes (25.72 and 26.67), cane length (2.23 and 2.16 m), single cane weight (1.57 and 1.41 kg), cane yield (225 and 204 t ha⁻¹) and water productivity (1.60 and 1.46 t ha cm⁻¹), respectively in plant and ratoon cane. Lower yield parameters were recorded with 100 and 75 per cent RDF.

Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher number of millable canes (26.67 and 27.76), cane length (2.37 and 2.27 m), single cane weight (1.73 and 1.55 kg), cane yield (255 and 227 t ha⁻¹) and water productivity (1.82 and 1.62 t ha cm⁻¹) in plant and ratoon cane, respectively. Whereas, on par results were observed with drip fertigation upto 9.5 months with 100 and 75 per cent RDF. However, normal method of cane cultivation under surface irrigation recorded significantly lower yield and yield parameters.

Drip fertigation up to 9.5 months recorded significantly higher CCS percentage (13.48 and 13.26 %) and sugar yield (29.97 and 28.86 t ha⁻¹) in plant and ratoon cane, however on par results was observed with drip fertigation upto 8 months.

CCS and sugar yield was found to be non significant. However, numerically higher CCS per cent (12.92 and 12.73 %) and sugar yield (26.98 and 25.23 t ha⁻¹) was obtained with 125 per cent RDF as compared to 100 and 75 per cent RDF.

Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher CCS per cent (13.60 and 13.38 %) and sugar yield (30.58 and 29.25 t ha⁻¹), respectively and was on par with drip fertigation upto 9.5 months with 100 and 75 per cent RDF. However normal method of cane cultivation under surface irrigation recorded significantly lower CCS per cent and significantly lower sugar yield.

Drip fertigation upto 9.5 months recorded significantly higher jaggery recovery percentage and jaggery yield (13.82 and 13.45 %) and (31.92 and 28.19 t ha⁻¹) in plant and ratoon cane and which was on par with drip fertigation upto 8 and 6.5 months.

Higher jaggery recovery percentage (13.22 and 12.85 %) and jaggery yield (28.42 and 24.40 t ha⁻¹) was observed with 125 per cent RDF under drip fertigation. However, numerically lower jaggery recovery and jaggery yield was observed with 100 and 75 per cent RDF under drip fertigation, respectively.

Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher jaggery recovery (13.96 and 13.55 %) and jaggery yield (32.21 and 28.91 t ha⁻¹). Whereas on par results were observed with drip fertigation upto 9.5 months with 100 and 75 per cent RDF, 8.0, 6.5 and 5 months irrespective of fertigation levels. However normal method of cane cultivation under surface irrigation recorded significantly lower jaggery recovery percentage and jaggery yield.

Significantly higher available N (365.97 and 336.10 kg ha⁻¹), P₂O₅ (47.63 and 45.43 kg ha⁻¹) and K₂O (273.91 and 260.86 kg ha⁻¹) at harvest was observed with drip fertigation upto 9.5 months in plant and ratoon cane, respectively and was on par with

drip fertigation upto 8.0 and 6.5 months with respect to N and upto 8.0 months with respect to P_2O_5 and K_2O .

Drip fertigation with 125 per cent RDF recorded higher available N (357.59 and 325.78 $kg\ ha^{-1}$), P_2O_5 (44.90 and 43.26 $kg\ ha^{-1}$) and K_2O (264.22 and 251.88 $kg\ ha^{-1}$) as compared to 100 and 75 per cent RDF in both plant and ratoon cane.

Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher available N (367.71 and 344.38 $kg\ ha^{-1}$), P_2O_5 (48.45 and 46.76 $kg\ ha^{-1}$) and K_2O (274.83 and 262.29 $kg\ ha^{-1}$) in plant and ratoon cane, respectively and was on par with drip fertigation upto 9.5 months with 100 and 75 per cent RDF, 8.0 and 6.5 months with all fertigation levels. Normal method of cane cultivation under surface irrigation recorded significantly lower available N, P_2O_5 and K_2O in plant and ratoon cane, respectively.

Significantly, higher N uptake (342.16 and 330.16 $kg\ ha^{-1}$), P uptake (45.84 and 42.95 $kg\ ha^{-1}$) and K uptake (261.67 and 234.00 $kg\ ha^{-1}$) was observed with drip fertigation upto 9.5 months in both plant and ratoon cane. However, it was on par with drip fertigation upto 8.0 months.

Drip fertigation with 125 per cent RDF recorded non significantly, higher N uptake (330.47 and 318.40 $kg\ ha^{-1}$), P uptake (43.02 and 41.23 $kg\ ha^{-1}$) and K uptake (249.83 and 220.49 $kg\ ha^{-1}$) was recorded with 125 per cent RDF and lower N, P and K uptake was revealed with drip fertigation with 100 and 75 per cent RDF in both plant and ratoon cane.

Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher N uptake (345.41 and 334.41 $kg\ ha^{-1}$), P uptake (46.22 and 43.22 $kg\ ha^{-1}$) and K uptake (264.96 and 237.29 $kg\ ha^{-1}$). However, on par results were observed with drip fertigation upto 9.5 months with 100 and 75 per cent RDF. Surface irrigation recorded significantly lower available NPK uptake in plant and ratoon cane.

Drip fertigation upto 9.5 months recorded significantly higher N (1.0 and 0.90 $t\ kg^{-1}$), P (2.50 and 2.24 $t\ kg^{-1}$) and K (2.0 and 1.79 $t\ kg^{-1}$) use efficiency in plant and ratoon cane, respectively and it was on par with drip fertigation upto 8.0 months N (0.94 and 0.85 $t\ kg^{-1}$), P (2.34 and 2.12 $t\ kg^{-1}$) and K (1.87 and 1.70 $t\ kg^{-1}$) use efficiency in plant and ratoon cane respectively.

Drip fertigation level with 125 per cent RDF recorded non significantly, higher nitrogen use efficiency (0.9 and 0.82 $t\ kg^{-1}$), phosphorus use efficiency (2.25 and 2.04 $t\ kg^{-1}$) and potassium use efficiency (1.8 and 1.63 $t\ kg^{-1}$) in both plant and ratoon cane, respectively.

Drip fertigation upto 9.5 months with 125 per cent RDF recorded significantly higher nitrogen use efficiency (1.02 and 0.91 $t\ kg^{-1}$), phosphorus use efficiency (2.55 and 2.27 $t\ kg^{-1}$) and potassium use efficiency (2.04 and 1.82 $t\ kg^{-1}$) in plant and ratoon cane, respectively and was on par with drip fertigation upto 9.5 months with 100 and 75 per cent RDF, respectively. However normal method of cane cultivation under

surface irrigation recorded significantly lower N, P and K use efficiency in plant and ratoon cane.

Drip fertigation upto 9.5 months recorded higher gross return, net return and B:C ratio in plant and ratoon cane (₹. 549687 and 493233 ha⁻¹), (₹. 441121 and 410268 ha⁻¹) and (5.06 and 5.95), respectively.

Drip fertigation with 125 per cent RDF recorded higher gross return and net return in plant and ratoon cane (₹. 494187 and 449466 ha⁻¹) and (₹. 382755 and 363634 ha⁻¹), respectively and lower gross return and net return was observed with drip fertigation with 100 and 75 per cent RDF. Whereas, higher B:C ratio was observed with 75 per cent RDF (4.51 and 5.42) as compared to 100 and 125 per cent RDF in both plant and ratoon cane.

Interaction effect of drip fertigation upto 9.5 months with 125 per cent RDF recorded higher gross return and net return (₹. 560325 and 499538 ha⁻¹) and (₹. 448893 and 413706 ha⁻¹) in plant and ratoon cane, respectively. Higher, B:C ratio was observed with drip fertigation upto 9.5 months with 75 per cent RDF (5.12 and 6.07) in both plant and ratoon cane. Normal method of cane cultivation under surface irrigation with 100 per cent RDF recorded lower gross return, net return and B:C ratio in both plant and ratoon cane.

Fertigation scheduling upto 9.5 months with 75 per cent RDF can be recommended for enhanced productivity and profitability of sugarcane under subsurface drip fertigation.

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APPENDIX I

Nutrient management in the experiment

STAGE	N	P	K
Surface irrigation			
BASAL	10 %	50 %	100 %
45 DAP	20 %	-	
75 DAP	30 %	-	
105 DAP	40 %	50 %	

Note:

DAP: Days after planting

FYM : Farm yard manure was applied at 25 t ha⁻¹ for all the treatments

APPENDIX II

Fertigation schedule for the experiment

Fertigation duration	No. of equal splits	75 % RDF		100 % RDF		125 % RDF	
		Urea (g)	MOP (g)	Urea (g)	MOP (g)	Urea (g)	MOP (g)
3.5 months	28	196	76	262	101	328	126
5.0 months	40	138	53	183	71	230	88
6.5 months	52	106	41	142	55	177	68
8.0 months	64	86	33	115	44	143	55
9.5 months	76	72	28	97	37	121	47

SSP applied in two equal splits as soil application as per requirement

Treatments	Total (kg)	1 st split (planting)	2 nd split (105 DAP)
75 % RDF	6.34	3.17	3.17
100 % RDF	8.45	4.22	4.22
125 % RDF	10.56	5.28	5.28

APPENDIX III

Cost of inputs and prices of output

Sl. No.	Particulars	Unit	Cost unit ha ⁻¹ (₹)	Units used ha ⁻¹	Cost ha ⁻¹ (₹)
1	Land preparation				
	-Disc plough and harrowing	Hour	700	20	14000
	-Earthing up			4	2800
-Shoulder breaking**	4			2800	
2	Labour				
	a)FYM/Press mud spreading	Man day (8 Hrs.)	200	12	2400
	b)Planting			8	1600
	c)Gap filling			6	1200
	d)Surface irrigation #			30	6000
	e)Drip irrigation			20	4000
	f)Fertilizer application #			16	3200
	g)Weeding			90	18000
	h)Plant protection chemicals			1	200
	i)Wrapping			20	4000
j)Harvesting	60			12000	
3	Inputs				
	a) Setts	Tonne	3200	4	12800
	b) FYM/Press mud	Tonne	1000	25	25000
	c) Fertilizers				
	-Urea	Kg	6.40	*	*
	-SSP	Kg	7.43	*	*
	-White Potash	Kg	16.05	*	*
d) Plant protection chemicals					
-Metribuzin	g	6	600	3600	
4	Drip fertigation unit (life span of 5 years)	-	-	-	13500
5	Cane	Tonne		2200	*

Note: * Units and cost varies according to treatment.

** Only for ratoon crop.

Only for surface irrigated treatment.

APPENDIX IV

Treatment wise detailed cost of cultivation for plant crop

Treatment details	Fixed cost	Irrigation cost	Fertigation cost	Total cost of cultivation
Fertigation up to 3.5 months with 75 % RDF	93100	4000	8599.26	105699.26
Fertigation up to 3.5 months with 100 % RDF	93100	4000	11465.64	108565.64
Fertigation up to 3.5 months with 125 % RDF	93100	4000	14331.97	111431.97
Fertigation up to 5.0 months with 75 % RDF	93100	4000	8599.26	105699.26
Fertigation up to 5.0 months with 100 % RDF	93100	4000	11465.64	108565.64
Fertigation up to 5.0 months with 125 % RDF	93100	4000	14331.97	111431.97
Fertigation up to 6.5 months with 75 % RDF	93100	4000	8599.26	105699.26
Fertigation up to 6.5 months with 100 % RDF	93100	4000	11465.64	108565.64
Fertigation up to 6.5 months with 125 % RDF	93100	4000	14331.97	111431.97
Fertigation up to 8.0 months with 75 % RDF	93100	4000	8599.26	105699.26
Fertigation up to 8.0 months with 100 % RDF	93100	4000	11465.64	108565.64
Fertigation up to 8.0 months with 125 % RDF	93100	4000	14331.97	111431.97
Fertigation up to 9.5 months with 75 % RDF	93100	4000	8599.26	105699.26
Fertigation up to 9.5 months with 100 % RDF	93100	4000	11465.64	108565.64
Fertigation up to 9.5 months with 125 % RDF	93100	4000	14331.97	111431.97
Control: Soil application of 100 % RDF with surface irrigation	93100	6000	3200	102300

APPENDIX V

Treatment wise detailed cost of cultivation for ratoon crop

Treatment details	Fixed cost	Irrigation cost	Fertigation cost	Total cost of cultivation
Fertigation up to 3.5 months with 75 % RDF	67500	4000	8599.26	80099.26
Fertigation up to 3.5 months with 100 % RDF	67500	4000	11465.64	82965.64
Fertigation up to 3.5 months with 125 % RDF	67500	4000	14331.97	85831.97
Fertigation up to 5.0 months with 75 % RDF	67500	4000	8599.26	80099.26
Fertigation up to 5.0 months with 100 % RDF	67500	4000	11465.64	82965.64
Fertigation up to 5.0 months with 125 % RDF	67500	4000	14331.97	85831.97
Fertigation up to 6.5 months with 75 % RDF	67500	4000	8599.26	80099.26
Fertigation up to 6.5 months with 100 % RDF	67500	4000	11465.64	82965.64
Fertigation up to 6.5 months with 125 % RDF	67500	4000	14331.97	85831.97
Fertigation up to 8.0 months with 75 % RDF	67500	4000	8599.26	80099.26
Fertigation up to 8.0 months with 100 % RDF	67500	4000	11465.64	82965.64
Fertigation up to 8.0 months with 125 % RDF	67500	4000	14331.97	85831.97
Fertigation up to 9.5 months with 75 % RDF	67500	4000	8599.26	80099.26
Fertigation up to 9.5 months with 100 % RDF	67500	4000	11465.64	82965.64
Fertigation up to 9.5 months with 125 % RDF	67500	4000	14331.97	85831.97
Control: Soil application of 100 % RDF with surface irrigation	67500	6000	3200	76700

Effect of Duration and Levels of Subsurface Drip Fertigation on Yield and Yield Parameters of Sugarcane

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ABSTRACT

A field experiment was conducted at ZARS, V.C. Farm, Mandya during 2014-15 to study the performance of sugarcane as influenced by duration and levels of subsurface drip fertigation. Results revealed that fertigation scheduling up to 9.5 months recorded significantly higher yield and yield parameters viz., millable canes m^{-1} row length (26.45), cane length (2.30 m), internodes cane $^{-1}$ (19.77), cane girth (3.23 cm), single cane weight (1.70 kg) and cane yield (250 t ha $^{-1}$). Yield and yield parameters significantly not influenced by fertigation levels. The interaction between duration of fertigation and fertigation levels were significant. Fertigation up to 9.5 months with 125 per cent RDF recorded significantly higher yield and yield parameters viz., millable canes m^{-1} row length (26.67), cane length (2.31 m), internodes cane $^{-1}$ (19.90), cane girth (3.26 cm), single cane weight (1.73 kg) and cane yield (255 t ha $^{-1}$) than normal method of sugarcane cultivation with surface irrigation with 100 per cent RDF soil application 147 t ha $^{-1}$ and was on par with fertigation upto 9.5 months with 100 per cent of RDF (249 t ha $^{-1}$) and fertigation upto 9.5 months with 75 per cent of RDF (246 t ha $^{-1}$). Thus results clearly indicated that 25 per cent of the recommended dose of fertilizer could be saved with 75 per cent higher cane yield through sub surface drip irrigation over normal practice of sugarcane cultivation.

SUGARCANE (*Saccharum officinarum* L.), one of the major cash crops in India has a unique role in sustaining agro industrial economic growth of our country. India is the world's second largest producer of sugarcane in terms of area (5.3 m ha) and production (366 m t) with a productivity of 69 t ha $^{-1}$ contributing 19.98 per cent of world's total (27.1 m t) sugar production (Anon., 2015). Globally, sugarcane is cultivated in an area of about 24.5 m ha with an annual production of 1850 m t and an average productivity of 75.5 t ha $^{-1}$ (FAO, 2015). In Karnataka, it is cultivated in an area of about 0.50 m ha with a production of 47 m t with an average productivity of 94.0 t ha $^{-1}$ (Anon., 2015).

Adoption of modern frontier technologies would become necessary to overcome many of the problems faced by sugarcane farmers. Under the circumstances, the technologies namely drip irrigation and fertigation etc. will have to be put to use on farm level for enhancing productivity with improved water and nutrient use efficiency. Sugarcane being a long duration crop, its normal irrigation water requirement

is relatively higher compared to other crops, which ranges from 1400 to 3000 mm ha $^{-1}$ depending on crop yield and climate. Traditional, flood irrigation often results in leaching of mobile nutrients which in turn leads to pollution of water bodies and deterioration of soil health. On the other hand, drip fertigation facilitates the optimum utilization of water and nutrients. Combined application of water and fertilizers is ideal for proper crop growth, as the irrigation water is acting as a carrier for the nutrients required by crops. In this way the soluble fertilizers are conveyed directly to the feeding zone through frequent application in small quantities through drip irrigation system. When properly managed, it opens up new avenues for growing crops under conditions similar to those of nutrient solution. This approach reduces nutrient losses, mainly N, due to leaching and as a result fertilizer recovery or use efficiency is relatively high. The amount of fertilizers lost through leaching can be as low as 10 per cent in fertigation. In the traditional system, 50 per cent loss is quite typical. Further, the ratios of fertilizers can be adjusted easily through the drip system. Considering all these points, a field experiment was conducted to study the performance of sugarcane under subsurface

drip irrigation with varied fertigation scheduling and fertigation levels.

The experiment was conducted at ZARS, VC, Farm Mandya, during 2014-15. Soil of the experimental site was red sandy loam with low organic carbon (0.46 %), medium available N (292.5 kg ha⁻¹), available P₂O₅ (38.2 kg ha⁻¹) and available K₂O (178.3 kg ha⁻¹). Experiment was laid out in factorial randomized complete block design, replicated thrice consisting of two factors-fertigation scheduling upto 3.5, 5.0, 6.5, 8.0 and 9.5 months and fertigation levels of 75, 100 and 125 per cent RDF with soil application of 100 per cent RDF with surface irrigation (control). The land was prepared by ploughing with tractor drawn disc plough followed by disc harrowing and passing cultivator twice to bring the soil to fine tilth. Layout was prepared with gross plot size of 15.0 X 9.0 m. Drip irrigation system was installed which included pump, filter units, main line and sub line. The laterals were placed at 1.95 m apart. The drip line was passed in between 30 cm apart paired row at 20 cm below the surface of soil. Inline emitters were placed 40 cm apart with discharge rate of 4 lph. Recommended FYM (25 t ha⁻¹) was applied one month before planting of sets. Out of the recommended dose of fertilizer (250: 100: 125 kg NPK ha⁻¹), 50 percent P was applied as basal dose and remaining P was applied at 105 days after planting (DAP) while earthing up for drip irrigated plots wherein, entire dose of N and K was applied through subsurface drip fertigation at different duration of 3.5, 5.0, 6.5, 8.0 and 9.5 months with three fertigation levels of 75, 100 and 125 per cent RDF consisting 28, 40, 52, 64 and 76 splits of fertigation respectively, twice in a week and drip irrigation was scheduled for every two days. Soil application of recommended dose of fertilizer, (250: 100: 125 kg of NPK ha⁻¹) with surface irrigation was considered as normal method of cultivation (control).

Viable and healthy two budded sugarcane sets were planted in a zig-zag manner in paired row method of planting with spacing of (165+30) X 30 cm. Co-86032 variety was used for planting. Weed management was done through Metribuzin 70 per cent @ 600 g ha⁻¹ at 2-3 days after planting. Optimum

plant population was maintained by filling the gaps at 30 DAP. Hand weeding was done at 45 and 90 days after planting to keep plots weed free. Earthing up was carried out by tractor drawn implement. In each plot five plants were selected randomly and tagged for recording growth and yield observations as per standard procedures. The data was statistically analyzed by following the method of Gomez and Gomez (1984).

Yield and yield parameters of sugarcane were significantly influenced by duration of fertigation (Table I). Fertigation up to 9.5 months recorded significantly higher yield and yield parameters *viz.*, millable canes m⁻¹ row length (26.45), cane length (2.30 m), internodes cane⁻¹ (19.77), cane girth (3.23 cm), single cane weight (1.70 kg) and cane yield (250 t ha⁻¹). But the yield and yield parameters of sugarcane were not significantly influenced by fertigation levels. This variation in yield and yield parameters under subsurface drip fertigation was mainly due to early vigorous growth which was attributed to required availability of water and nutrients due to better wetting pattern, water distribution in soil and relative water use by the crop throughout the crop growth stage which meets the crop demand (Deshmukh *et al.*, 2001). The interactions between duration of fertigation and fertigation levels were significant. The fertigation up to 9.5 months with 125 per cent RDF recorded significantly higher yield and yield parameters *viz.*, millable canes m⁻¹ row length (26.67), cane length (2.31 m), internodes cane⁻¹ (19.90), cane girth (3.26 cm), single cane weight (1.73 kg) and cane yield (255 t ha⁻¹). The increase in yield and yield parameters under subsurface drip irrigation might be due to efficient water and nutrient utilization, higher absorption and accumulation of nutrients by crop and maintenance of excellent soil water relationship in the root zone of the sugarcane (Dhotre *et al.* 2008).

The conventional method of cane cultivation recorded the lowest yield of 147 t ha⁻¹. This might be due to considerable wastage of plant nutrients due to alternate drying and wetting with loss of nutrients through deep percolation below root zone and volatilization particularly nitrogen resulting in

TABLE I

Yield and yield parameters of sugarcane as influenced by duration and levels of subsurface drip fertigation

	Millable canes m ⁻¹ row length	Cane length (m)	Internodes cane ⁻¹	Cane girth (cm)	Single cane weight (kg)	Cane yield (t ha ⁻¹)
Duration of fertigation						
T ₁	24.01	2.08	17.92	2.88	1.40	192
T ₂	25.23	2.15	18.61	2.97	1.46	206
T ₃	25.69	2.19	18.97	3.08	1.54	220
T ₄	25.98	2.24	19.39	3.16	1.61	234
T ₅	26.45	2.30	19.77	3.23	1.70	250
S.Em±	0.67	0.05	0.52	0.08	0.04	6.06
CD (p=0.05)	1.94	0.15	1.51	0.24	0.11	17.50
Levels of fertigation						
L ₁	25.18	2.17	18.68	3.03	1.51	216
L ₂	25.51	2.19	19.00	3.06	1.55	220
L ₃	25.72	2.21	19.13	3.10	1.57	225
S.Em±	0.52	0.04	0.41	0.06	0.03	4.69
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction						
T ₁ L ₁	23.22	2.04	17.16	2.83	1.37	189
T ₁ L ₂	24.15	2.08	18.24	2.88	1.41	192
T ₁ L ₃	24.65	2.12	18.37	2.93	1.42	195
T ₂ L ₁	24.97	2.13	18.48	2.94	1.44	201
T ₂ L ₂	25.29	2.14	18.61	2.96	1.45	206
T ₂ L ₃	25.45	2.16	18.74	3.01	1.49	210
T ₃ L ₁	25.57	2.17	18.83	3.04	1.52	216
T ₃ L ₂	25.69	2.20	18.99	3.08	1.55	219
T ₃ L ₃	25.83	2.21	19.10	3.11	1.56	224
T ₄ L ₁	25.91	2.23	19.26	3.14	1.58	230
T ₄ L ₂	25.99	2.24	19.38	3.16	1.61	234
T ₄ L ₃	26.03	2.26	19.53	3.19	1.63	239
T ₅ L ₁	26.23	2.28	19.65	3.21	1.65	246
T ₅ L ₂	26.43	2.29	19.77	3.23	1.71	249
T ₅ L ₃	26.67	2.31	19.90	3.26	1.73	255
Control	21.05	1.96	17.05	2.79	1.28	147
S.Em±	1.16	0.09	0.91	0.14	0.06	10.50
CD (p=0.05)	3.36	0.26	2.62	0.41	0.19	30.32

Duration of fertigation

T₁: Fertigation up to 3.5 MonthsT₂: Fertigation up to 5.0 MonthsT₃: Fertigation up to 6.5 MonthsT₄: Fertigation up to 8.0 MonthsT₅: Fertigation up to 9.5 Months

Levels of fertigation

L₁: 75% RDF, L₂: 100% RDF, L₃: 125% RDF

Control: Soil application of 100% RDF with surface irrigation.

RDF: 250: 100: 125 kg of NPK ha⁻¹

imbalance in soil water metabolism and nutrient environment (Ridge and Hewson, 2002). Similar findings were also reported by Lin Xu *et al.* (2010).

Thus, subsurface drip fertigation helps to increase cane yield by 67-73 per cent besides saving water and 25 per cent nutrients over conventional method of sugarcane cultivation.

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Effect of Fertigation Scheduling and Fertilizer Levels on Yield, Quality and Commercial Cane Sugar Production under Subsurface Drip Fertigated Sugarcane

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ABSTRACT

Field investigation was carried out at Zonal Agricultural Research Station (ZARS), V. C. Farm Mandya, UAS, GKVK, Bangalore, Karnataka during 2014-15 to study the effect of fertigation levels and fertigation scheduling on yield, quality and commercial cane sugar production of sugarcane under subsurface drip fertigation. The results of the experiment revealed that fertigation scheduling upto 9.5 months has given on par results on the quality parameters viz brix (19.85%), pol (18.92%), purity (95.42%), reducing sugar (3.30%) and CCS (commercial cane sugar production) (13.65%). Similar results was also observed under fertigation levels upto 125 per cent RDF (recommended dose of fertilizer) recorded quality parameters viz brix (20.26%), pol (19.34%), purity (95.63%), reducing sugar (3.20%) and CCS production (13.84%) and the interaction effect between fertigation scheduling and fertigation levels also followed the same trend recorded quality parameters viz brix (19.80%), pol (18.85%), purity (95.38%), reducing sugar (3.31%) and CCS production (13.60%). In comparison with conventional method of sugarcane cultivation recorded lower quality parameters viz brix (19.72%), pol (18.80%), purity (95.16%), reducing sugar (2.82%) and CCS (13.34%). Significantly higher cane yield was observed under fertigation scheduling upto 9.5 months (250 t ha⁻¹) and higher cane yield (225 t ha⁻¹) under fertigation levels @ 125 per cent RDF. The interaction effect between fertigation scheduling and fertigation levels are significant, the fertigation up to 9.5 months with 125 per cent RDF recorded significantly higher cane yield (255 t ha⁻¹) while conventional method of cane cultivation recorded significantly lower cane yield (146 t ha⁻¹). This clearly indicates that increment in the fertigation scheduling and fertigation levels does not affect the quality and CCS production of sugarcane under subsurface drip fertigation. However, significantly higher cane yield can be obtained under fertigation scheduling and fertigation levels without affecting the quality and CCS production.

Key words: *Saccharum officinarum*, Subsurface drip irrigation, Fertigation, Growth, Yield

Sugarcane (*Saccharum officinarum* L.), one of the major cash crops in India has a unique role in sustaining agro industrial economic growth of our country. India is the world's second largest producer of sugarcane in terms of area (5.3 m ha) and production (366 m t) with a productivity of 69 t ha⁻¹ contributing 19.98 per cent in world's total (27.1 m t sugar) sugarcane production (Anonymous 2015). Globally, sugarcane is cultivated on 24.5 m ha with an annual production of 1850 m t with an average productivity of 75.5 t ha⁻¹ (FAO 2015). In Karnataka, it is cultivated on 0.50 m ha with a production of 47 m t with an average productivity of 94.0 t ha⁻¹ (Anonymous 2015). Adoption of modern frontier

technologies would become necessary to overcome many of the problems faced by sugarcane farmers. Under the circumstances, the sophisticated tools and technologies namely drip Irrigation and fertigation etc will have to be put to use on farm level for enhancing production with improved water and nutrient use efficiency, monitoring crop condition, and assessment of crop acreage and production. Sugarcane being a long duration crop, its normal irrigation water requirement is relatively higher compared to other crops, which ranges from 1400 to 3000 mm ha⁻¹ depending on crop yield and climate traditional system of flood irrigation often results in leaching of mobile nutrients which in turn leads to pollution of water bodies and deterioration of

soil health. On the other hand, fertigation under drip facilitates the optimum utilization of water and nutrients. Fertigation is a technique of application of water-soluble fertilizers through the irrigation systems. Combined application of water and fertilizers is ideal for proper crop growth, as the irrigation water is acting as a carrier for the nutrients required by crops. In this way the soluble fertilizers are conveyed directly to the feeding zone through frequent application of soluble fertilizers in small quantities through drip irrigation system. When properly managed, it opens up new avenues for growing crops under conditions similar to those of nutrient solution. This approach reduces nutrient losses, mainly of N, due to leaching and as result fertilizer recovery or use efficiency is relatively high as a result of all these higher cane yield can be achieved and the quality parameters of cane are not affected through drip fertigation. While the conventional method of cane cultivation leading to various losses of applied nutrients, affecting the yield and quality parameters of cane. Keeping this in view, present study was conducted to know the performance of sugarcane under varied levels of fertigation scheduling and fertigation levels through subsurface drip fertigation.

MATERIALS AND METHODS

The experiment was conducted at ZARS, V. C. Farm Mandya, during 2014-15. Soil of the experimental site was red sandy loam with low OC (0.46%), medium available N (292.5 kg ha⁻¹), available P₂O₅ (38.2 kg ha⁻¹) and available K₂O (178.3 kg ha⁻¹). Experiment was laid out in factorial randomized complete block design, replicated thrice consisting of two factors Factor A fertigation scheduling upto 3.5, 5.0, 6.5, 8.0 and 9.5 months and Factor B fertigation levels of 75, 100 and 125 per cent RDF with control soil application of 100 per cent RDF with surface irrigation. The land was prepared by ploughing with tractor drawn disc plough followed by disc harrow and passing cultivator twice to bring the soil to fine tilth. Layout was prepared with gross plot size of 15.0 × 9.0 m. Drip irrigation system was installed which included pump, filter units, main line and sub line. The laterals were placed at 1.95 m apart. The drip line was passed in between paired rows at 20 cm below the surface of soil. Inline emitters were placed 40 cm apart with discharge rate of 4 lph. Recommended FYM (10 t ha⁻¹) was applied one week before planting of sets. Out of the recommended dose of fertilizer (250: 100: 125 kg NPK ha⁻¹), 50 percent P was applied as basal dose and remaining P was applied at 105 days after planting (DAP) while earthing up for drip irrigated plots wherein, entire dose of N and K is applied through subsurface drip fertigation at different intervals of 3.5, 5.0, 6.5, 8.0 and 9.5 months with three fertigation levels of 75, 100 and 125 per cent RDF consisting 28, 40, 52, 64 and 76 splits of fertigation respectively, twice in a week and drip irrigation was scheduled for every two days. Soil application of recommended dose of fertilizer, (250: 100: 125 kg of NPK ha⁻¹) as per package of practice surface irrigation was considered as control plot. Viable and healthy two budded sugarcane sets were planted in a zig-zag manner in paired

row method of planting with spacing of (165 + 30) × 30 cm. Co-86032 variety was used for planting. Weed management was done through Metribuzin 70% @ 600 g ha⁻¹ at 2-3 days after planting. Optimum plant population was maintained by filling the gaps at 30 DAP. Hand weeding was done at 45 and 90 days after planting to keep plots weed free. Earthing up was carried out by tractor drawn implement. Healthy plant population was maintained by following plant protection measures and recommended package of practices. In each plot five plants were selected randomly and tagged for recording growth and yield observations as per standard procedures. The data was statistically analyzed by following the method of Gomez and Gomez (1984).

Purity (%)

It is the ratio of pol per cent juice to the corrected degrees brix expressed in percentage and the values were computed as per the following formulae:

$$\text{Purity coefficient} = \frac{\text{Pol percent juice}}{\text{Corrected brix \%}} \times 100$$

Commercial cane sugar (CCS %)

The values of commercial cane sugar on per cent cane basis were computed from the following formulae:

$$\text{CCS per cent cane} = \left[\text{S} - (\text{B} - \text{S}) \times 0.4 \right] \times 0.73$$

Where, S= Sucrose per cent in juice

B= Brix per cent in juice

RESULTS AND DISCUSSION

Quality parameters and CCS production of sugarcane was not affected when grown under subsurface drip fertigation (Table 1). Fertigation scheduling upto 9.5 months has given on par results on the quality parameters viz brix (19.85%), pol (18.92%), purity (95.42%), reducing sugar (3.30%) and CCS (13.65%). Similar results was also observed under fertigation levels upto 125 per cent RDF recorded quality parameters viz brix (20.26%), pol (19.34%), purity (95.63%), reducing sugar (3.20%) and CCS production (13.84%) and the interaction effect between fertigation scheduling and fertigation levels also followed the same trend recorded quality parameters viz brix (19.80%), pol (18.85%), purity (95.38%), reducing sugar (3.31%) and CCS production (13.60%). In comparison with conventional method of sugarcane cultivation recorded lower quality parameters viz brix (19.72%), pol (18.80%), purity (95.16%), reducing sugar (2.82%) and CCS (13.34%). This might be due to split application of required fertilizer doesn't affect the quality parameters (Raskar and Bhoi 2001). Shinde *et al.* (2003) reported that improvement in juice quality due to fertigation treatments over conventional method. More *et al.* (2005) observed that improvement in juice quality with increase in fertilizer levels. The brix, purity and CCS per cent were on par with application of 125 per cent RDF than with 75 per cent RDF. But the pol per cent was higher with the application of 100 per cent RDF. Juice analysis, however, indicated no significant differences in CCS per cent when fertilizer was supplied through subsurface drip irrigation (Deshmukh *et al.* 2001).

Yield, Quality and Commercial Cane Sugar Production under Subsurface

Significantly higher cane yield was observed under fertigation scheduling (250 t ha⁻¹) and higher cane yield (225 t ha⁻¹) under fertigation levels. The interaction effect between fertigation scheduling and fertigation levels are significant, the fertigation up to 9.5 months with 125 per cent RDF recorded significantly higher cane yield (255 t ha⁻¹). This increase in cane yield under subsurface drip fertigation was mainly due to early vigorous growth which was attributed to required availability of water and nutrients due to better wetting pattern, water distribution in soil and relative water use by the crop throughout the crop growth stage which meets the crop demand (Deshmukh *et al.* 2001).

The increase in yield under subsurface drip fertigation might be due to efficient water and nutrient utilization, higher absorption and accumulation of nutrients by crop and maintenance of excellent soil water relationship in the root zone of the cane (Dhotre *et al.* 2008). While conventional method of cane cultivation recorded significantly lower cane yield (146 t ha⁻¹) this is mainly due to considerable wastage of plant nutrients and water under surface irrigation due to considerable wastage of plant nutrients and water in deep percolation below root zone resulting in imbalance in soil water and nutrient environment (Ridge and Hewson 2002). Similar findings were reported by Lin *et al.* (2010).

Table 1 Effect of yield, quality and CCS production under subsurface drip fertigated sugarcane

Treatments	Brix (%)	Pol (%)	Purity (%)	CCS (%)	Reducing sugar (%)	Cane yield (t/ha)
Fertigation scheduling						
T ₁	20.77	19.82	95.93	14.15	3.03	191.93
T ₂	20.59	19.61	95.81	14.00	3.10	205.87
T ₃	20.31	19.43	95.68	13.87	3.19	219.93
T ₄	20.07	19.24	95.55	13.76	3.25	234.27
T ₅	19.85	18.92	95.42	13.65	3.30	249.86
S.Em ±	0.52	0.46	1.28	0.51	0.10	6.06
CD (p=0.05)	NS	NS	NS	NS	NS	17.50
Fertilizer levels						
L ₁	20.37	19.45	95.72	13.93	3.15	216.51
L ₂	20.33	19.41	95.68	13.88	3.18	219.97
L ₃	20.26	19.34	95.63	13.84	3.20	224.63
S.Em ±	0.40	0.36	0.99	0.40	0.08	4.69
CD (p=0.05)	NS	NS	NS	NS	NS	NS
Interaction						
T ₁ L ₁	20.81	19.87	95.98	14.20	3.00	189.00
T ₁ L ₂	20.77	19.83	95.93	14.14	3.04	192.19
T ₁ L ₃	20.73	19.75	95.89	14.09	3.05	194.60
T ₂ L ₁	20.68	19.65	95.85	14.04	3.07	201.26
T ₂ L ₂	20.61	19.61	95.80	14.00	3.10	206.00
T ₂ L ₃	20.50	19.56	95.77	13.95	3.14	210.35
T ₃ L ₁	20.36	19.49	95.73	13.91	3.17	216.29
T ₃ L ₂	20.33	19.43	95.68	13.87	3.19	219.15
T ₃ L ₃	20.25	19.37	95.62	13.83	3.22	224.34
T ₄ L ₁	20.11	19.29	95.59	13.80	3.24	230.12
T ₄ L ₂	20.09	19.25	95.55	13.76	3.25	233.50
T ₄ L ₃	20.00	19.18	95.50	13.73	3.27	239.18
T ₅ L ₁	19.89	18.98	95.46	13.69	3.28	245.86
T ₅ L ₂	19.85	18.92	95.41	13.65	3.29	249.02
T ₅ L ₃	19.80	18.85	95.38	13.60	3.31	254.69
Control	19.72	18.80	95.16	13.34	2.82	146.52
S.Em ±	0.90	0.80	2.22	0.88	0.18	10.50
CD (p=0.05)	NS	NS	NS	NS	NS	30.32

Factor A: Fertigation scheduling

- T₁: Fertigation up to 3.5 Months
- T₂: Fertigation up to 5.0 Months
- T₃: Fertigation up to 6.5 Months
- T₄: Fertigation up to 8.0 Months
- T₅: Fertigation up to 9.5 Months

Factor B: Fertilizer levels

- L₁: 75% RDF
- L₂: 100% RDF
- L₃: 125% RDF
- Control: Soil application of 100% RDF with surface irrigation

Sugarcane cultivation under subsurface drip fertigation helps to increase cane yield besides saving water and nutrients over conventional method of sugarcane cultivation. In addition to this sugarcane quality and commercial cane sugar production was not affected with increment in the fertigation scheduling and fertigation levels.

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